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Intégration des considérations environnementales en entreprise: Une approche systémique pour la mise en place de feuilles de routes

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ABSTRACT

FR Pour traiter des défis écologiques et créer de nouveaux avantages concurrentiels, les entreprises ont besoin de considérer et d'intégrer les aspects environnementaux dans tous les processus de l'entreprise. De nombreuses méthodes environnementales existent, ainsi que des solutions visant leur intégration dans les processus de l'entreprise. Mais la revue de la littérature montre qu'une approche systémique combinant besoins stratégiques et pratiques de l'éco-conception pourrait favoriser cette intégration.

Cette thèse, qui s'intègre dans le module « tactique » du projet national ANR-Convergence,vise à fournir un nouveau cadre d'analyse, s'appuyant sur un ensemble de méthodes environnementales. Ce cadre doit permettre d'identifier et de planifier une séquence d'actions appropriée pour une meilleure intégration de l'environnement en entreprise. Ainsi, une analyse claire, visant l'identification de l'ensemble des méthodes et solutions existantes et l'identification de leurs interrelations a été menée. Notre travail a ainsi consisté à identifier les corrélations opérationnelles entre les méthodes via une cartographie, puis a mettre en évidence des relations entre ces méthodes et les besoins dynamiques des entreprises. Ceci nous a permis de proposer au final une approche systémique pour la création de feuilles de route environnmentales en entreprise. Ces feuilles de route vont s'adresser aussi bien aux niveaux stratégiques, tactiques qu'opérationnels des entreprises.

Les résultats de trois expérimentations menées montrent que les propositions ci-dessus conduisent bien à la création de feuilles de routes appropriées aux besoins réels et souvent dynamiques des entreprises. Ces feuilles de routes tracent ainsi les actions à mener et indiquent les potentiels outils à leur associer, afin d'identifier le processus opérationnel réel et d'organiser le flux de travail entre les différentes fonctions de l'entreprise.

Mots clés: Intégration, Systémique, Feuille de route, Management Environnemental, Support Décisionnel, Planification, Trajectoires, Cohérence, Flux d'information

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EN To answer environmental challenge and create new competitive advantages, the companies need to consider and integrate environmental considerations into all its processes. Numerous environmental methods exist as well as solutions to integrate them into companies. But, the literature review realised indicates that a systemic approach combining strategic and practical needs from eco-design could facilitate this integration.

This thesis, which represents the "tactic" module of the national research project ANR- Convergence, aims to provide a new framework to identify a suitable operational trajectory for a better integration of environmental consideration in companies. Thus, a clear analysis about the identification of these existing methods and their interrelationships was realised. Our work was to identify the operative correlation between methods via a cartography, then the relationship between those methods and the dynamic needs/contexts of companies to finally propose " environmental roadmaps. So, we finally propose a systematic approach to define environmental roadmaps in companies.Those roadmaps concern the strategis, tactic and operational levels in companies.

The results of three academic/industrial experiments demonstrate that all proposals of this thesis could ensure effectively the identification of a suitable systemic trajectories' group based on actual corporate needs and its dynamic context. The pre-defined chain of action and the list of available tools provided support the company to identify the working process and to organize the workflow between different corporate functions.

Key words: Systemic Integration, Roadmap, Environmental Management, Decision Support, Planification, Trajectory, Coherence, Informational Flow

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Introduction

To answer environmental challenge and create new competitive advantages, the companies need to consider and integrate environmental considerations into all its processes. Numerous environmental methods exist as well as solutions to integrate them into companies. But, the literature review realized indicates that a systemic approach combining strategic and practical needs from eco-design could facilitate this integration.

This thesis, which represents the "tactic" module of the national research project ANR-Convergence, aims to provide a new framework to identify a suitable operational trajectory for a better integration of environmental consideration in companies. Thus, a clear analysis about the identification of these existing methods and their interrelationships was realized. Our work was to identify the operative correlations between methods via cartography, then the relationship between those methods and the dynamic needs/contexts of companies to finally propose environmental roadmaps. So, we finally propose a systematic approach to define environmental roadmaps in companies. Those roadmaps concern the strategies, tactic and operational levels in companies.

The results of three academic/industrial experiments demonstrate that all proposals of this thesis could ensure effectively the identification of a suitable systemic trajectories' group based on actual corporate needs and its dynamic context. The pre-defined chain of action and the list of available tools provided support the company to identify the working process and to organize the workflow between different corporate functions.

The structure of this manuscript is organized as follow:

The first "Part I" contains three chapters to present the current situation about the implementation of "environmental concerned mechanism" in industry. In order to provide a systemic view on this situation, this part does not only present the principal external environmental drivers to push the industry moving forward to the “ecologically necessary” (Chapter 1), it also analyzes the implemented environmental program to show how the industry answers the external requirements and meets the need of corporate sustainable development (Chapter 2). Meanwhile, a summary about the vast number of existing environmental methods and industrial practices have been presented into chapter 3. Finally, the conclusion of this part focuses on the “diversity” in the environmental domain, which includes the diversity of external legal requirements, customer needs, the diversity of implemented corporate program and the diversity of the existing environmental methods.

Facing to the diversity of environmental related issues, the “Part II” further illustrates three scientific problematic in order to optimize the environmental integration into the company. The chapter 4 illustrates the lack of evaluative mechanism that could provide a systemic view on the relationship among the different environmental method (series and parallel) and provide a robust identification of a holistic decision, depending on its dynamic context. Next, the chapter 5 focuses on the interactions between the environmental activities of site-oriented approach and product-oriented approach. The conclusion of this chapter 5 demonstrates that there is a positive influence to take into account all relationships among eco activities and that there is a lack of systemic integrative mechanisms to combine all approaches of environmental activities. Then, the chapter 6 provides a global point of view to indicate that the environmental integration needs a systemic approach to optimize the decisional and informational circulation among the whole company, from the strategic decision to operational daily processes.

Finally, the chapter 7 concludes that a systemic model is necessary to organize the overall integration of environmental actions. This model needs to: 1) make the coherence between selected eco-methods and manage the flow of information exchanged; 2) make the coherence between environmental decision and the corporate objectives and contexts; and 3) make the coherence between corporate tendency and the project’s requirements (the global approach of site-oriented environmental management and product-oriented improvement). Meanwhile, this systemic model needs to be integrated into a better decisional circulation among whole company to presents a positive effect on the "sustainability" integration.

The “Part III” illustrates the propositions of this thesis to resolve these three aspects of the problematic. Firstly, the chapter 8 presents a global approach called “vertebral column” model, to provide a holistic definition about the responsibilities of each hierarchical level: strategic, tactic and operational levels. Then, three applicable scenarios have been proposed to describe the movement of decisional flow. This thesis considers the “tactic” module of this approach to propose several different operational scenarios to realize the strategic requirements and select a suitable one. The detailed specifications of this module lead to the research works that are presented into next chapters. Chapter 9 and 10 present how to realize a depth analysis about the identification of existing environmental methods and the interaction among them. The chapter 9 presents the general hypothesis and the methods of the analysis and the chapter 10 provides a systemic cartography of environmental actions. Then, according to this static database, the chapter 11 illustrates how to dynamically generate the several operational trajectories to answer the environmental objectives and how to select the suitable one by considering several indicators. In this chapter, several use contexts have been also presented.

The “Part IV” provides the sequence of experiments that enrich knowledge in the practice of environmental integration and get the demonstration of the validity of the scientific propositions. The chapter 12 presents an academic experiment by designing a serious game “SimGreen” to validate if above propositions might support the systemic environmental integration. Next, in order to ensure the robustness of the proposals for the “Tactic module”, Two experiments were organized in two companies: the chapter 13 presents the case study into Quiksilver that is one of the world’s leader about outdoor sports lifestyle and chapter 14 presents the second industrial case study into Festilight that is a SME (small or medium-size enterprise) for decorative and festive lighting service. Then the chapter 15 summarizes that the “Tactic module” successfully provides a systemic and depth support to ensure the achievement of pre-defined environmental objectives. The multiple “scenarios map” provides a large systemic view of potential solutions at the corporate functions level (for large groups) or at the workers (for SMEs).

Finally, the “Part V” summarizes the scientific contribution and the limits of this thesis research.

I

POSITIONING

In order to curb and prevent degradation of the planet, society must change to formulate a new socially and culturally acceptable proposal. The management of environmental consideration indicates that a framework at industrial level is connecting “ecologically necessary” with “technically possible”. This part is to present the actual situation about the implementation of “environmental concerned mechanism” in industry. In order to provide a systemic view on this situation, this part does not only present the principal external environmental drivers to push the industry moving forward to “ecologically necessary”, it also analyzes the implemented environmental program to show how the industry answers the external requirements and meets the need of corporate sustainable development. Finally, the conclusion focuses on the “diversity” in the environmental domain, which includes the diversity of external legal requirements, customer needs and the diversity of implemented corporate program. This “diversity” leads to the following research about a systemic environmental consideration to optimize the integration of environmental aspects into company.

Chapter 1 - Various Environmental Drivers

In recent decades, worldwide, the environmental problems lead some risks that cannot be neglected by human society. In one generation, the world population has grown from two to more than six billion people. It is estimated that if all mankind had the same level of life that Westerners, we should have two to five Earths to meet all needs. Additionally, the ever-increasing industrial pollution, and the increasing volume of waste treatment accelerate the climate change and reduce the comfortable living space. Facing this alarm signals that affect all humanity, it becomes clear that our models of consumption and production are no longer viable. To prevent degradation of the planet, society must change to formulate a new socially and culturally acceptable proposal, the management of environmental consideration is connecting the "ecologically necessary" with "the classic technical possibility"[1].

1.1. Various drivers for environmental activities

The protection of the earth is the most basic reason to implement the environmental concerned practices. But this reason is too abstract, and its results aren't measurable. So, why does industry choose to implement environmental activities? Why are certain environmental indicators integrated? The answers of these two questions might be a start point in order to formulate the prototype of integration system for environmental activities.

In 1998, by conducting a survey of 77 Dutch SMEs[2], [Van Hemel C., 1998] provides details on the incentives of integration of the environmental considerations:

- Environmental laws/directive and Industrial initiatives
- Requirement of customers and local communities
- Opportunities of new business success by technical innovation and a green corporate image

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[1] Original, the product design and related production process ensure the product's function and productivity. Today, the sustainable development and the environmental management require the company to focus on the environmental impacts during the whole life cycle of product.

[2] SME – Small or Medium size Enterprises. According to the "commission recommendation of 6 May 2003 concerning the definition of micro, small and medium-sized enterprises - 2003/361/EC", The category of micro, small and medium-sized enterprises (SMEs) is made up of enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding 50 million euro, and/or an annual balance sheet total not exceeding 43 million euro.

[Essid M., 2007] further explicated that 87% of Respondents (companies) is for optimizing the economic performance, 85% for respecting the laws and industrial initiatives and 83% for improving the relationship with community (public and local government) in order to gain new clients. [Kengpol A. and Boonkanit P., 2011] and [Gurauskiene I., 2006] indicated that the risks and the opportunities of green supply chain, which could be considered as an important operational performance of business success, is also a driver to move the industry.

1.2. 1st driver - diversity of legal and Industrial standardization

Environmental laws, which draw from and is influenced by principles of environmentalism, including ecology, conservation, stewardship, responsibility and sustainability, is an efficient and frequently-used pattern to require the industries to protect the environment and sustainability of future human society [Ziegler A., 2009]. Since 1970s, the Europe has focused on the environmental protection. In order to avoid the impact-transfer among different environmental issues, these laws or directives cover a wide range of environmental topics, from hazardous substance control, air pollution, energy performance of products to waste treatment requirements. Some important examples, such as directives like RoHS3, REACH4, WEEE5 and IPPC6, take a great role to accelerate the environmental progress and educate the public to take care of the environment. The next table synthesizes various European environmental legal topics.

3 **RoHS:** The objective of "Directive for Restriction of the use of the certain Hazardous Substances - 2002/95/EC is to limit the use of certain substances hazardous (mercury, cadmium, lead, Hexavalent chromium, PBB, PBDE and DecaBDE) in electrical and electronic equipment. The producer should declare a file in order to present the compliance. This directive fundamentally impacts the design, re-design existing.

4 **REACH:** Regulation for the Registration, Evaluation, Authorization and Restrictions of Chemicals - 2006/121/EC in force since 1 June 2007, aims to improve the protection of human health and the environment. This regulation requires the registration of all chemical substance, especially, the hazardous substance (SVHC – Substance Very High Concern). Producer must declare the weight or volumes of SVHCs contained and ensure a total responsibility in the management of such SVHCs according to security dash. The permissible and complete forbidden list of SVHCs will be enforced for a deeply environmental improvement. The substances of RoHS have been considered as the first forbidden substance list.

5 **WEEE**: Directive on the Waste of Electric and Electronic Equipment – 96/61/EC is to promote the recycling of EEE. Since August 2005, the waste of EE equipments covered by this directive must be separately collected and properly recycled. The producer/importer must ensure that the product's recyclability rate can achieves a minimum percentage.

6 **IPPC:** The objective of Integrated Pollution Prevention and Control Directive - 96/61/EC is to promote the prevention of the integrated pollution. This directive requires all industrial high pollution potential to be certified by a permit that is according to the "BAT - Best Available Technology".

Europe[7]	- **Tackling climate change** General framework policy, Kyoto protocol, Reduction of greenhouse emissions, Energy, Transport, Innovation - **Sustainable development** Sustainable development strategy, Integration of environmental policy - **Waste management** Prevention and recycling of waste, Specific waste, Package waste, Dangerous waste, Radioactive waste - **Noise pollution** Noise management, Specific sources - **General provision** Eco label, Chemical Substance - **Energy efficiency** Energy efficiency of products, Buildings and services - **Air pollution** Air quality, Atmospheric pollutants, Transport, Industry - **Water protection and management** Water usage, Marine pollution, Inland waters, Discharge of substances

Table 1-1: The various topics of European environmental legislation

The format and the contents of environmental laws are not uniform. Depending on the controlled objects, the requirements of laws and directives related to industrial activities, could be divided into major groups: controlling the environmental performances of the whole life cycle of product (including the material selection, the manufacturing process, the packaging, the use performance and end of life treatment) and controlling the organizational activities (including the take back system organization, the noise and the emission controlling). According to the controlled topics, these requirements might be divided into two subjects: the resource conservation and related management, and the pollution control and remediation. According to the format of laws, these laws might also be divided into three different types: firstly, the establishment of mandatory threshold value for environmental issues (Air, water emission, recyclability rate and prohibition of hazardous substances, etc.), secondly the suggestions and guidelines for global environmental impacts improvement and thirdly the management system to generate, organize, follow up and register the environmental related data and idea.

Today, the environmental legislation might become more stringent. In the energy label framework, the minimum market-entering threshold of energy efficiency value is frequently reviewed and upgraded. The SVHC-Substance Very High Concern list of REACH directive annually grows up (from 15 substances in 2008 to 84 substances at end of 2012). The

[7] List of some examples concerned with industry. Data source from EU (European Union Official Website): http://europa.eu/legislation_summaries/environment/index_en.htm

perimeter of EuP directive is enlarged. Now it covers some energy related products. These upgrading of laws continuously push the industry to optimize the technologies and reject the backward manners for fulfilling all demands.

Beside of European legislation, in order to develop a more stringent legal control for environmental protection, almost all main industrial countries, such as the united states, Australia, Japan, China and Korea, etc., develop, implement, and enforce a solid environmental law framework. These laws or directive cover also various environmental topics. The table 1-2 lists some examples.

Japan	- Law for the Promotion of Effective Utilization of Resources (Named also Japan RoHS) - Energy Conservation law (top runner standard) - Home Appliance Recycling Law etc.
US	- California electronics waste material (display) recycle law (Maine, Maryland also established the recycle law) - Confederative energy policy law (established in 2005) - Mercury regulation (Vermont etc.)
China	- Regulations on Promotion of Utilization of Recyclable Resources - Administration on the Control of Pollution Caused by Electronic Information Products (Chinese RoHS) - Regulations on Recycling and Disposal of Waste and Used - Household Electrical Appliances (China WEEE)
Korea	- The Act for Resource Recycling of Electrical and Electronic Products and Automobiles - Resource conservation and facilitation of the recycling law (including Korea RoHS)

Table 1-2: Some examples of worldwide environmental legislation

Worldwide, even for same topic, the implementing patterns of same environmental laws are different. It's because of the difference of local severity of environmental problems and its local cultures (for example, the different volumes of hazardous substances in local marketing with different degree of prevention). The most obvious example is the different local version of RoHS (till now, 6 local versions have been established[8]). Among each version, the substances list, the concerned product's categories and the implementing pattern of each version are not uniform. The Table 1-3 illustrates the difference between EU RoHS and China RoHS.

Item	**EU RoHS**	**China RoHS**	**Implications**
Enforce	1st July 2006	1st March 2007	
Geography	EU - Europe	China	

[8] There are California (USA) RoHS, China RoHS, Japan RoHS, Korea RoHS, Norway RoHS and Turkey RoHS.

Product Scope	EEE [a]	Current: EIP [b] Future: EIP → EEE	Will be closely aligned with EU-RoHS
Substances	Lead, Mercury, Cadmium, Hexavalent chromium, PBB, PBDE and **DecaBDE**	Lead, Mercury, Cadmium, Hexavalent chromium, PBB, PBDE and **Other substances**	The substance scope of China-RoHS is larger than Europe
Certification	Not necessary Self-declaration is OK	Self-declaration and Mandatory "CCC[9]" certification for certain substances	
Marking	No required	China RoHS Logo on product [c]	
Exemptions	39 exemptions due to technical limitation	Exemption not allowed. Need to declare the presence of hazardous substance in a table with orange RoHS logo	EU exemptions are not applicable to China RoHS. They can't be used in China to achieve RoHS compliant.
Packaging	Out of scope [d]	Packaging material has to be marked [e]	Packaging requirement is explicitly highlighted.

Note:
[a] EEE: Electric and Electronic Equipment
[b] EIP: Electronic Information Product
[c] China RoHS provides two logos. The green logo is for compliant product and orange one is for no-compliant product.
[d] Requirements of package is under "Packaging and Packaging Waste Directive - 94/62/EC"
[e] According to existing packaging standard GB18455-2001.(Recycle symbol, Green point marking)

Table 1-3 Comparison between EU RoHS and China RoHS

Preliminarily, the China RoHS is stricter because it does not allow the exception. But in fact, although product isn't compliant with China RoHS, it's also possible enter into local market with the declaration and labelling conditions. Inversely, this product is forbidden to sell if it's not be covered by exception. Additional, due to the exception rules, the product in Europe is RoHS compliant, but in China, it's not. This product should provide the declaration files and labels. These differences lead to a difficulty for company, the same design of product might be sold in one local market, but not in others, and vice versa.

So the legislation is a principal driver for environmental activities, but because of the multi-topics, the diversity of subjects/formats, the frequently upgraded requirements and the difference among worldwide laws, the industry should face a stricter and more complex

[9] The China Compulsory Certificate mark, commonly known as CCC Mark, is a compulsory safety mark for many products imported, sold or used in the Chinese market. It became implemented on May 1, 2002 and fully effective on August 1, 2003

legislative environment. And this complexity leads to a more and more difficult integration of environmental activities into corporate daily work.

1.3 2nd driver - Green final market/Customers

With the great contribution from numerous scientific studies and strong promotion on environment, the management of environmental impacts has been gradually accepted, understood and focused on by the government, the industry and the public.

A global report (2010)[10] showed that the green market outperformed the US economy as a whole in 2009 and grew by over 40% from 2004 to 2009. And in 2010, more than a third of US consumers now say they are willing to pay a premium for eco-friendly products, and in some cases this is even higher, for example 53% of US consumers would be willing to pay a premium for a greener television, according to the Consumer Electronics Association. Another example from UK, according to a 2009 Carbon Trust study, 44% of UK consumers want more information on what companies are doing to be green.

Facing this more and more "greener" public, the satisfaction of these "green" requirements is an important driver for industry to integrate the environmental activities into the "blood" of product design and daily organizational activities.

But, words, like "Green" or "Environment", are very abstract. In order to release this object, the industry must break it down into some concrete action categories or attributes that can be understood, quantified and addressed [Hallstedt S., et al., 2010]. So some features of market demands, are interested to be analyzed in order to support the industry to decide what actions or attributes need to be implemented and how to do them.

At theoretical level, the analysis of each individual needs is not enough to support the understanding of a global situation. Depending on three following points, an analysis of existing criteria of "Type I Eco labelling" system is considered as an indirect, but efficient solution to synthesize the characteristics and features of market demands:

- The purpose of type I eco label system

[10] Global Ecolabel Monitor report 2010, released by BIG room Inc. and World Resources Institute
Website: http://www.ecolabelindex.com/

"Type I Eco label" is a certificated label system for product or organizational activities. According to the environmental criteria of each product category, this eco label certifies and communicates that the overall preferences of labeled product or organization is less stressed on the environment. The general objective of eco label is to facilitate purchasing decisions (with or without the eco label), thereby stimulating the potential for market-driven continuous environmental improvement" [ISO 14024, 1999].

Eco label is direct and simple to use. The customer doesn't need special knowledge to judge if the product or organization is green. For type I eco label, the certification of independent third party is trustable, especially, some have the governmental background. For example, a survey by German "Blue Angel" eco label system[11] pointed out that 38% of respondents believe that Eco label has led to a clear improvement in the environmental quality of their products.

So a successful and well-known type I eco label system could affect and induce the movement of public's environmental requirements toward the criteria of eco label.

- The market acceptance of eco label system

Till 2010, there are over 370 eco label systems in 214 countries and 25 industry sectors in the world for multi-criteria environmental certificate[12].

The eco label system is now accepted by the public and presents a grand influence on public purchasing decision. A report from ADEME[13] [Machefaux M., 2012] showed that the recognition rate of the European Ecolabel is increasing. In 2009, 37% of consumers surveyed reported having seen / heard or bought labeled products against 11% in 2006. A survey by German "Blue angel" eco label system pointed out that 83% of respondents know the Blue Angel and 49% of German citizens pay attention to the Blue Angel when shopping[14].

Meanwhile, some scientific literatures indicated similar conclusion regarding the positive impact of eco-labelling system on customer behaviors [Gallastegui I.G., 2002] and

[11]Data and information from official website of "blue angel eco label"
http://www.blauer-engel.de/en/blauer_engel/index.php
[12]Global Ecolabel Monitor report 2010, released by BIG room Inc. and World Resources Institute
Website: http://www.ecolabelindex.com
[13]ADEME: French Environment and Energy Management Agency. It's a public agency to encourage, supervise, coordinate, facilitate and undertake operations for protecting the environment and managing energy.
[14]Data and information from official website of "blue angel eco label"
http://www.blauer-engel.de/en/blauer_engel/index.php

[Grankvist et al., 2007] make generic analysis, [Lundquist et al., 2006] and [Teisl et al., 2007] indicate the influence in vehicle domain and [Gottberg et al., 2006] in electrical equipments.

- The considered issues during the establishment process of the criteria

  By analyzing the process of criteria's establishment, a committee is constituted by the experts from environmental conservation, administrative organs concerned and the customer affairs[15]. This multi-disciplinary organization ensure that the criteria cover all necessary check points, which includes the significant environmental impacts, the social hot points and the common requirements from marketing. Meanwhile, the criteria of eco labelling system are frequently updated and modified to answer the changing of public's demand and integrate the new technologies.

The Global Eco label Network (GEN) is a network of non-profit organizations around the world that organizes the main type I eco label. The international network is to contribute to the augment of credibility and collaborability among worldwide label system. At the end of 2012, the GEN included 26 national and multinational members. Through GEN's website[16], the details of technical criteria of each product category of each label system are accessible. The following table 1-4 summaries 22 eco labelling system analyzed which covers almost all main economical entities.

Europe	European Union, Nordic countries, France, Germany, Russia, Spain, Sweden, Croatia and Czech
North America	U.S.A. and Canada
Asia Pacific	China, Japan, Korea, India, Australia, Singapore, Philippines, Thailand, Hong Kong, Taiwan and new Zealand

Table 1-4: Summary of worldwide type I eco labelling

Each eco labelling system covers multi-product's categories/types, and there is a special related technical document to list all environmental criteria for each category. In order to simplify the analysis and ensure the comparability among different labelling system, the criteria exploration is limited into EEE - Electric, Electronic Equipment domain.

[15] An example from Japan "Eco Mark" system – the process of criteria establishment http://www.ecomark.jp/english/unei.html

[16] http://www.globalecolabelling.net/

By analyzing details of each criterion, the results indicate that the voluntary requirements for each product's category are not uniform.

The first difference is related to the objects of implementation. The criteria of labels not only require some better environmental performances of final product; also they ask some different organizational activities in order to protect the environment during the production and end of life phase. Sometimes, the informational declaration is required to provide the necessary information to auditor and public.

The second difference is related to the required environmental indicators or activities. Although there are some common hot points (such as the energy efficiency, the hazardous material controlling and the declaration system) which are always highlighted, some other indicators and activities are mentioned and required. An example from sensor and switching devices: there are 3 eco labelling systems covering this product's category, 3 labels require the health care of occupants and the energy efficiency. Additional, there are 2 labels which require the hazardous substance control, water and air pollution control during the production phase. And 1 of 3 labels set up the requirements on lifetime, recycling rate, GHG - Green House Gas emission and sol pollution during the production phase. Because each eco labelling system is only available in its region, this diversity of requirement is not convenient for international companies which need to face the international market. These companies must implement different solutions to resolve different needs.

The third difference refers to the format of requirements. Although for same topic, the contents of requirement are different. The same example from sensors and switch devices, for indicator of "human health", American "green seal" requires a safety model and a backup manual control, but Japanese and Indian "Eco Marks" focus on the noise level during the usage phase. A same situation appears also for the "energy efficiency" indicator. American requires a minimum consumption within the covered area, but Japanese focuses on the value of energy consummation.

The fourth difference is related to the strictly degree of requirements. Even if the criteria are similar (such as the life time of product or the hazardous substance list), the requirements are not identical. Each label has his special threshold values or description form.

The next table 1-5 indicates the diversity of required environmental criteria (for EEE products) of 22 eco labels. The product categories are classified in two product groups: the electric/electronic product and the electric/electronic related process. For each product's category, the numerals in first column "Nb of eco label concerned" present how many eco labels cover this category and establish the related environmental criteria. The following columns indicate the list of required environmental indicators or activities, which includes the final product checking points (Such as Health care, energy efficiency, etc.) and the indicators during production process (Sol, Water and Air pollution, for example). The related numerals show how many environmental criteria mention and require such indicator or activity. Finally, the percentage presents the distribution of required indicators or activities for each product group.

	Environmental Indicator & Required Activities														
	Nb of Eco Label concerned	Health	Energe efficiency	Hazardous substance	Lifetime	Natural ressources	Water consumption	Recycle	Waste/biodegradable	Sol pollution	Water pollution	Air pollution	GHG	Ozone-deleting	Information/Management
Electric/Electronic Products		69%	80%	93%	29%	2%	8%	59%	34%	19%	24%	38%	9%	19%	69%
Sensors and switching devices	3	3	3	2	1			1		1	2	2	1		2
Electric Chillers	10	8	10	9	3			7	3	1	2	3	2	9	8
Photovoltaic Cells	5		4	5	3			1		2	2	2	1	1	3
Printer	12	12	12	12	3			12	7	2	2	11	1		9
Audiovisual Equipment	9	4	9	9	3	1		9	4	2	3	3			9
PC (Monitor, Notebook)	12	9	12	10	5	1		9	6	1	1	1		1	7
Air Conditioners	6	5	6	6				3	2	1	2	2		4	6
Electric cable	2	2	1	2											1
Batteries	8	2	2	8	4			1	3	3	4	4			3
Mobile phone	5	5		5				3	3						5
Car/moto	3	2	1	3				1		1	1	3	3		
Transformer	2	2	2	1				1		1	1	1			1
1000V (AC) EE component	1			1				1						1	1
Washing machine/dishwasher	7	5	7	6	3		7	2	1	1	1	1			4
Printed and Writing Board	1			1											
Process		57%	100%	71%	0%	29%	71%	86%	71%	14%	14%	0%	14%	0%	86%
Facilities operation and maintenance	3	2	3	2			1	3	2	1					2
Lodging Properties	4	2	4	3		2	4	3	3		1		1		4

Table 1-5: The required criteria of 22 eco labels for electric and electronic equipment

Comments:

- *Health: This indicator requires the characteristics of product to take care of the human health. The noise level and emission during the use phase, and the security control mode are three common examples.*
- *Energy efficiency: This indicator requires the efficiency of energy used during the use phase. The units of different label's requirements are not similar. Some requires the consumable threshold and other set the minimum functions by the unit of energy consumption.*
- *Natural resource: This indicator, primary concern with the paper and imprinter, requires the limit of natural resource use.*
- *Water consumption: This indicator is often mentioned for the water consumption during the production phase. Some consumption in use phase has been mentioned also.*

- *Recycle: this indicator requires some threshold of end of life performance. The take-back system is mentioned also.*
- *Waste/biodegradable: This indicator requires some features concerning waste of product. Some waste treatment processes are required also in certain labels.*
- *Sol, Air and Water pollution: the indicator requires the environmental protection during the production phase*
- *GHG and Ozone depletion: this indicator requires the environmental protection during the production phase*
- *Information/Management: this indicator requires the company to set up an environmental management system and provides all necessary information to auditor or public.*

Through this table, for EEE products, the prioritized required environmental indicators and activities are:

- Hazardous substances control
- Energy efficiency
- Human's health (Noise level, electromagnetic field etc.)
- Declaration of environmental information
- Recycling or reuse of components and materials

For the service, the interested check point is almost same as EE product; it just takes care in addition of water consumption.

1.4 3rd driver - Competition/Business opportunities from green technologies/images

The third principal environmental drive is the high consideration about the marketing competition. Facing to this point, [Berry and Rondinelli, 1998] and [Porter, 1980] emphasized that the cost factor and the differentiation to create new business opportunities are two drives for implementing the environmental management. [De Bakker F.G.A., 2002] pointed out that a systemic environmental management set up a better overview on the actual or future cost structure could improve a corporate competition position. By the analysis of the existing initiatives of environmental management, [Shrivastava P., 1995a, b] provides some examples of business benefits, reduction of operating costs by exploiting ecological efficiencies, increased demand by attracting 'green' consumers, and a higher ability to influence or to go ahead of regulation to keep the technical leadership. [Christmann P., 2000] provides empirical evidence that the higher a corporate level of innovation in proprietary pollution prevention technologies is the larger the costs advantage it gains from environmental strategies. [Alvarez Gil, M.J., et al., 2001] demonstrated also the similar cost gains in service sector. Through the analysis of 243 companies, [Gonzalez-Benito J., 2005] indicated that the environmental management positively affects on business and competitive performance due to the development of some distinctive resources:

- The physical assets and technologies, could cultivate the distinctive capabilities and knowledge;
- Human resources and organizational capabilities
- Several Intangible resources are developed, such as reputation and the ability to influence public policies to achieve competitive advantages.

[Neely A., 1999] demonstrated the contribution of environmental concerned practices for three different area of business performance: the operational performance[17], the marketing performance[18] and the financial performance.

But, several authors indicated that there is no standard or single path to make a business success. [Vastag G. et al., 1996], [Bansal, P. and Roth, K., 2000] and [Gonzalez-Benito J., 2005] identified different environmental drivers which lead to a higher environmental pro-activity and they considered that each driver induces the implementation of a different portfolio of environmental practices. [Gonzalez-Benito J., 2005] summarized that the environmental concerned program does not necessarily means the following of a standard implementing path which includes a set of pre-formulated environmental management practices; rather, it can be manifested in different ways through different sets of practices.

Finally, [Gonzalez-Benito J., 2005] indicated that there are positive effects of environmental proactively on business performance and these effects are dependent on the types, the implementing manners of the portfolios of environmental practices is manifested.

1.5 Conclusion

This chapter summarizes three principal drivers to motivate the industry integrating the environmental considerations into their daily work. The legislation requires industry focusing

[17]Operational performance considers the effectiveness of the corporate daily operational system, the production, the stocking and the logistic network. Some traditional criteria, such as the cost of purchasing, the operational cost, the quality, the flexibility and the deliverability are demonstrated as some key points for affecting the competition.

[18]Marketing performance considers the effectiveness of the marketing function, that is, to the ability of the company to meet customer requirements. The indicator of reputation, new product launching success, or product adequacy to market needs reveals how able the company is to manage its relationships with customers and to satisfy them.

on the environmental protection. A more and more green market pushes the company to consider the environmental impacts of its product or related production activities. Meanwhile, the business opportunities from the green image encourage the industry to focus on some potential environmental improvements. But the diversity of requirements and the lack of a standard and clear successful business model lead to a more and more difficult implementation of suitable environmental related activities.

Chapter 2 - Diversity of Corporate environmental programs

Facing the diversity of environmental requirements, whether they are from the external demand (the legal and customer's requirement), or the internal needs for corporate development, the industry is acting to integrate the various environmental activities in its design/organizational process [JRC, 2000].

Today, the industry is considering three drivers to motivate the integration of environmental activities. But the contents of each driver are varied and dynamic. *So it's interesting to analyze, in practice, how the industry answers these requirements. Does these corporate strategies are uniform? Which and how many environmental indicators or activities have been or will be selected and implemented?*

2.1 Various environmental considerations at strategic level

At strategic level, the corporate attitude and the related environmental policy reflect the "diversity" for environmental consideration. Considering the analysis of several industrial cases, [Willard B., 2005] summarized that there are five models of sustainable integration:

- Model "Pre-compliance": the company defines the environmental issue as a barrier, without any benefits for corporate development. Due to the lack of a strong legal constraint, this company maintains the current practice without any integration of environmental consideration (at the risk of being outlawed). [Soparnot R., 2006] summarized that this behavior is less and less frequent because the risks (financial or otherwise) for violations of regulations are increasingly important.
- Model "Compliance": the environmental concerned issue is a negative creator of the legal constraints and some additional operational cost. So the company considers that any green investments are an unnecessary cost. But due to the legal constraints, they only obey the minimum mandatory laws and regulations on environmental, thus limiting the risk of offense involved in case of noncompliance with laws (cross-compliance). It is suitable for eco-defensive to minimize risk and investment with respect to minimum legal standards [Soparnot R., 2006].

- Model “beyond compliance”: the environmental concerned issue is considered as a new technical or communication standards which need to be implemented into the company. The exigencies of the environmental legal and the necessity for a green image of a company are two principal issues [Soparnot R., 2006].The company recognizes the opportunity to reduce the costs mainly through higher resource efficiencies and waste controlling, leading to both financial and ecological gains. But, environmental concerned issues are still independent and separated from core business development.
- Model “Sustainability”: The sustainable issue has been integrated in the company’s global vision and informs key business strategies to be more successful than competitors through innovation, design, and improved financial risk assessments. The company does not favor the immediate financial return; the related social and environmental investments are anticipated to produce effects in the longer term. According to Willard, very few companies in the world have yet implemented this model.
- Model “Purpose and passion”: According to the definition of Willard, this model is not for most actual company. It’s defined as an originally proposition to “help saving the world”.

Similarly, [Carroll A., 1979], [Bellini B., 2003] and [Soparnot R., 2006] provides a three hierarchical levels classification. The model “pre-compliance” and “Compliance” are named as the “eco-defender”; the “Beyond compliance” is named as the “eco-conformist” and the model “integrated strategy” is described as the “eco-sensible”. The last model “purpose and passion” is out of the scope of this classification.

Further, according to the implemented area, [Hedman J. and Henningsson S., 2011] classified three types of corporate environmental policies for IT equipment in electric and electronic domain:

- Storefront – creation of an image: this type of policy is without any change of their business activities, at least following the legal and mandatory requirements, review the existing to see if they could be labeled as green by the common rules or create new form of green. Some green purchasing or green investments for improving the green performance have been included. In this type, the environmental department is as an auditor, a communication department or a marketing role.
- Tuning – Improving the current operations: this type of policy requires some improvement for operational process, but without drastic changes. Some new machines (the CRT screen is replaced by LCD, etc.) or new habits (the virtual desktop replaces the paper, etc.)

- Redesign – Reinventing the company: this type of policy considers the environmental concerned issue as a new opportunities for corporate development. It allows the drastic change of ongoing, the process, the product and the corporate habit. Some initiative plans (like the environmental impacts reduction plan, involved into the organization and existing process) and investment should be launched for adapting the needs. But, due to the lack of successful stories in this domain, [Hedman J. and Henningsson S., 2011] indicated that the drastic changing might lead to a risky situation.

2.2 Diversity at Operational level for environmental consideration

At operational level, the results of an industrial survey [JRC, 2000] by European Union Joint research center for 500 European companies indicated that the industry has simultaneously focused on several environmental drivers at same time to organize their environmental corporate program. The business considerations are the primary drivers, such as the reduction of end of life cost, the new product/market opportunities, the legal and the customer's requirements, and some environmental concerns of secondary, likes producer responsibility and waste controlling for environment. Similar results were obtained in the Reyes's survey [Reyes T., 2008] indicated that the various environmental drivers are focused at the same time.

In order to answer the requirements of each environmental driver, multi-environmental activities are being implemented in the company. [JRC, 2000] indicated that 12 environmental topics have been considered. The most mentioned topic is environmental efficiency, the suits are environmental conscious design, recycling, durability, and some topics concerned with end of life improvement.

An industrial survey about corporate environmental activities till 2010 has been done to analyze the practical implementation situation of product-oriented environmental activities into enterprise. This survey focused on all functions inside the enterprise, from the environmental strategy, roadmap and management plan to technical realization methods. To ensure the comparability, the information of 22 international electrical or electronic (EEE) companies had been selected. They are competing into a same industrial domain and should face a worldwide marketing.

The sample of this survey came from some official materials, such as:

- The official presentations of corporate eco-design program
- The corporate sustainable annual reports

- The corporate criteria to evaluate the environmental impacts / profits of their products
- The rules of industrial associated program (IT Eco declaration, PEP-Eco passport etc.)
- Some other promotion materials (published papers, conference presentation, etc.)
- Face to face interviews with corporate environmental experts to discuss the corporate eco product program

The analysis of existing 29 "Eco design" or "Eco" communication program in 22 companies of EEE		General Improvement	Premier resource	Battery	Hazardous substance	Package Material	Manufacture	GHG	Ozone Depleting	Emission	Energe efficiency	Lifetime	Decomposition	Recyclability	Waste treatment	Document	Ergonomics
Frequency of citation for each Eco-action (presented in %)		21%	72%	10%	69%	52%	28%	34%	24%	17%	86%	59%	76%	90%	45%	41%	3%
Declaration	Eco Highlights Label (HP)		√								√	√		√	√		
Comparative criteria to evaluate the environmental performance	Green flagship (Philips)		√		√	√		√			√	√	√	√			
	Excellence ECP (TOSHIBA)		√	√	√	√	√	√	√	√	√	√	√	√	√		
	Environmental Label (Yamatake)	√	√			√		√		√	√	√	√	√		√	
	Eco Label (OMRON)	√	√				√				√	√	√	√			
	Super Eco Product (HITACHI)		√					√									
	Eco Friendly Label (Mitsubishi)		√		√						√	√	√	√			
	Environmental Label (Yokogawa)				√	√					√	√	√	√		√	
	High Grade Green Product (SII)	√	√		√	√	√				√	√	√	√		√	
	Ecomagination (G.E.)		√					√								√	
Check List with the pre-defined threshold for checking points	ECP (TOSHIBA)			√	√	√	√	√	√		√	√	√	√	√	√	
	Eco Product (HITACHI)		√			√					√	√	√	√	√		
	Super Eco product (FUJI)	√	√			√					√		√	√		√	
	Eco Product (FUJI)	√	√			√					√		√	√		√	
	Green Product (Matsushita)	√	√		√			√				√	√	√			
	Eco Symbol (NEC)		√		√	√	√		√		√	√	√	√		√	
	Eco Product 02 (EIZO)				√				√		√		√		√		
	Eco Product 04 (EIZO)				√				√		√		√	√	√		
	Eco Product 06 (EIZO)				√	√			√		√		√	√	√		
	Eco Product 09 (EIZO)				√	√			√		√		√	√	√	√	
	Green Label (Brother)		√		√			√			√			√	√		
	ECO2 (Renault)						√	√			√			√			
	Eco Mark (SAMSUNG)		√		√						√		√	√			
	Eco Friendly Product (TOYOTA)		√		√	√		√		√	√	√	√	√	√	√	
	Recycle Label (RICOH)				√					√	√			√	√		
	Green Product (SII)		√		√	√	√				√	√	√	√		√	
	Eco Symbol (SEC)		√		√		√					√	√	√	√		
	Super Green Product (Sharp)		√		√						√	√	√	√			
	IT Eco Declaration		√	√	√	√				√	√	√		√	√	√	√

Table 2-1: Overview of environment indicators selected by EEE enterprises

Comments:

- *"General improvement" describes the corporate requirements without special actions. Compared with the main competitor, it asks to achieve the top technical level of design and manufacture, etc.*
- *"Premier resource" includes some requirements about the reduction of product's weight, the mono-material requirements and the labeled plastic, etc*
- *"Battery" presents some requirements about battery's material, the design for dismantling and the depollution, etc.*
- *"Hazardous substance" requires the avoidance, the limitation of use and the declaration of hazardous material, etc.*
- *"Package material" requires the reduction of the package weight, the shape redesign and mono-material requirements, etc.*
- *"Manufacture" focuses on less pollution (air, water and land) during the manufacturing process, etc.*
- *"GHG -Greenhouse gas" and "Ozone depletion" present special requirements on those indicators.*

- *"Emission" requires the limit and the declaration of other emission (except GHG and ozone depletion gas) during the use phase, such as VOC and noise, etc.*
- *"Energy consumption" requires the improvement of energy consumption value during use phase. It also focuses on the energy efficiency which evaluates the consumption value depending on the functional performance.*
- *"Lift time" includes some propositions to prolong the life time of product. These propositions include design for dismantling and modularity, the redesign of the structure and the choice of materials.*
- *"Decomposition" presents the requirements for design for disassembly and decomposition guide, etc.*
- *"Recyclability" requires the recyclability rate of product for reused and recycled material in the product, etc.*
- *"Waste treatment" focuses on special contracts with the waste treatment center and the corporate take- back system of the products*
- *"Document" asks the establishment of eco design databases, which registers the collected eco data, the hypothesis and the evaluation methods and the assessment results, etc.*
- *"Ergonomist" asks some additional needs for easy fabrication, easy use and easy maintenance, etc.*

The table 2.1 presents a dashboard of the survey's results. The collected corporate environmental or green product programs are listed in the first left column. At the top of vertical lines are all the environmental indicators selected during the entire product's life cycle. The percentage presents the frequency of citation for the eco programs. For example, according to 29 eco design programs, 86% selected the "Energy efficiency" as one of the actions of their programs.

The results show a diversity of corporate environmental policy and related actions:

1, Till to the end of 2010, all 22 EEE enterprises have set up an internal environmental policy to improve or declare their environmental improvement.

2. The diversity of selected action's group

Because the hitting domain is the electric and electronic industry, the hotspots of environmental actions are "energy efficiency of using phase (86%)" and "the recyclability rate (90%)" of the final product. Aside of these two hotspots, other environmental actions during the entire life cycle of product have been also nominated many times, such as the package material (52%), documentation of eco database (41%) and the manufacture process improvement (28%). The table 2-1 shows that the final group of selected indicators by each enterprise is diver.

3. The diversity of technical criteria

The technical criteria of corporate eco product programs are classified in two main categories: the synthesis of environmental information of product (HP highlight label system, etc.) and the certification of green performance. To judge the green performances of product/service, those methods provide comparative criteria (compare the new product with a selected reference) and check lists which evaluate the product by some special thresholds (such as consumed value, avoidances, life time etc.).

Some companies have a very large volume of sales for green products. Brother and Panasonic have been labeled for 100% products, fulfilling the basic environmental requirements. The high grade environmental certification system and related label appeared to push the new improvement, to identify some better eco friendly products with current technique level (EIZO, 2007; EIZO, 2009).

4. The diversity of implementing process

The survey results show that some necessary environmental evaluations have been integrated into the R&D process, from the definition of the product specification to final validation. According to the different criteria and selected indicators group, the implementation process is different, such as the involved time for eco activities during the R&D process, the development of related tools, and the need of support from other corporate functions (product marketing, product quality and purchasing).

5. The diversity of communication format

According to different corporate environmental strategies, there are various formats to communicate the results. The type II eco labeling system (ISO 14024) is a major solution. In addition, the corporate defined communication files (type III label system) and some special certified labels (energy star etc.) have been implemented also by some enterprise.

2.3 Conclusion

This chapter summarized several strategic models and a various numbers of operational possibilities to integrate the environmental consideration. Whether at strategic level or operational level, the actual initiatives present a decisional diversity about the environmental integration. So finally, there is not a standard and uniform solution for all companies to treat the environmental issues. The establishment of environmental policies and related operational programs might be flexible depending on the consideration about the external/internal requirements, the dynamic corporate policy and its context. The diversity of selection and the large number of available eco methods require a mechanism to support the identification and the integration of suitable environmental strategy and related eco methods group.

Chapter 3 - Diversity of environmental methods

From previous chapters, it's clear that the industry is facing to a stricter and complex environment which requires the implementation of various environmental concerned considerations. The consideration of environmental aspects and sustainable development in the industry has changed a lot in 50 years, from reactive measures or curative to preventive measures on the production site, the product life cycle, and most recently for a systemic approach [IDP, 2008]. In order to adopt different behaviors, there are a mass of environmental concerns methods and tools that have been developed by academics or industrials.

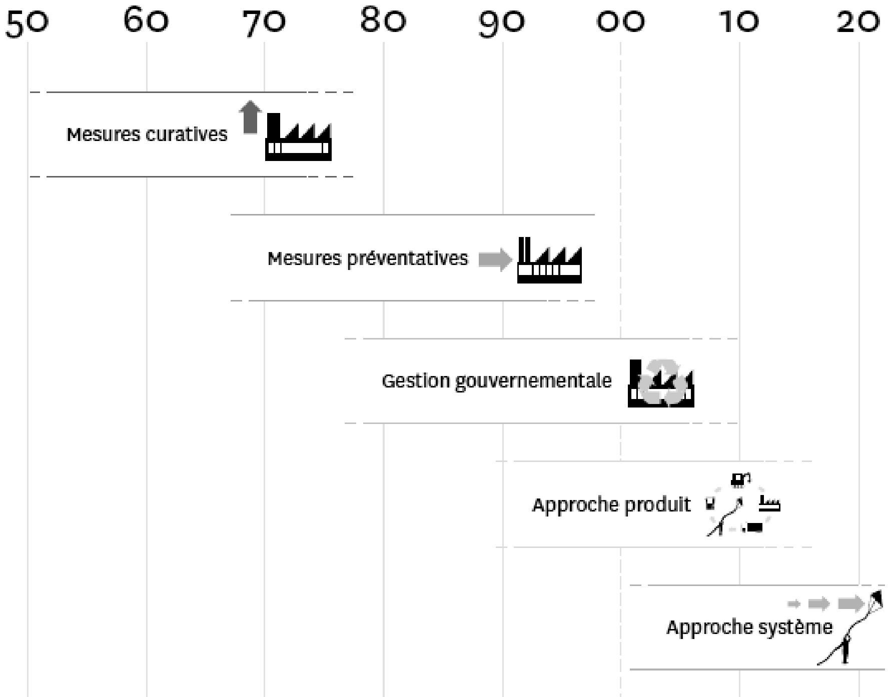


Figure 3-1: Historical development of the environmental concerned consideration [IDP, 2008]

According to the object and related frontier of analysis, [Reyes T., 2007] indicated that there are two principal approaches of environmental concerned considerations:

- The product-oriented environmental consideration (The product's environmental profits improvement activities throughout the whole life cycle of product)
- The organization-oriented consideration (Environmental management system approach confirmed with the boundary of firms).

3.1 The product-oriented environmental methods and tools

Due to the 80% of environmental impacts pre-defined at product design phase [EuP directive, 2007], the product-oriented environmental consideration, is usually named “Eco-design”, is an approach that takes into account the environmental aspects in the early stages of product or service design. This approach aims to reduce the negative impacts of a product or service on the environment and society throughout its life cycle, while maintaining its quality of use and performance. This approach is thinking in terms of life cycle, fits naturally in a process of product development. Any product contributes more or less to environmental degradation since it requires materials and energy must be transported and packaged, maintained and repaired and it will one day become a waste.

According to the definition of ISO 14044, the product’s life cycle for environmental domain, means the consecutive and interlinked stages of a product system, including the raw material acquisition or generation from natural resources, the material and product manufacturing, the final product distribution, the utilization and the final disposal steps. The geographic transport between the stages is also focused on. The life cycle approach of environmental analysis is to compile and evaluate the inputs/outputs and the potential related environmental impacts of a product system throughout its whole life cycle.

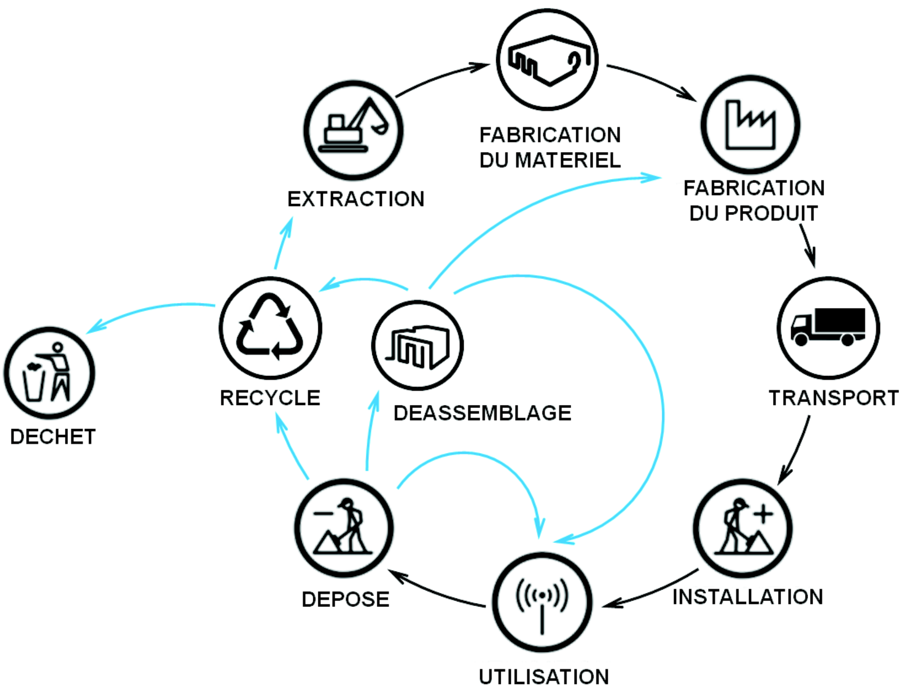


Figure 3-2: The product life cycle with different end of life treatments

Comments: According to different end of life treating manners, the material flow could be returned toward the utilization phase ("Reuse approach"), the product manufacturing phase ("Remanufacturing approach") and material manufacturing phase ("recycling approach")

Meanwhile, the environmental concerned consideration is not an independent issue. The precondition of an environmental improvement should ensure the product's functions. Several authors defined that the eco-design is a schematic solution to find out a great balance among the technical constraints, environmental concerns, and economic requirements [Brezet, 1997; Lagerstedt, 2003; Kobayashi, 2006; Al-Tuwaijri, 2004]. .

3.1.1 The diversity of product-oriented environmental methods and tools

After 20 years of development, there is a vast number of eco design approaches proposed. According to the different exigencies for environmental consideration, certain environmental methods provide a global evaluative view for product life cycle and some others focus on the detail design of certain environmental topics. According to the diversity of applicable domain, [Brezet, 1997], [Robert K.H., 2000] and [Reyes T., 2007] classified the eco design approaches into three main categories: the approach of "Design for X"; the life cycle analysis and the innovative eco design.

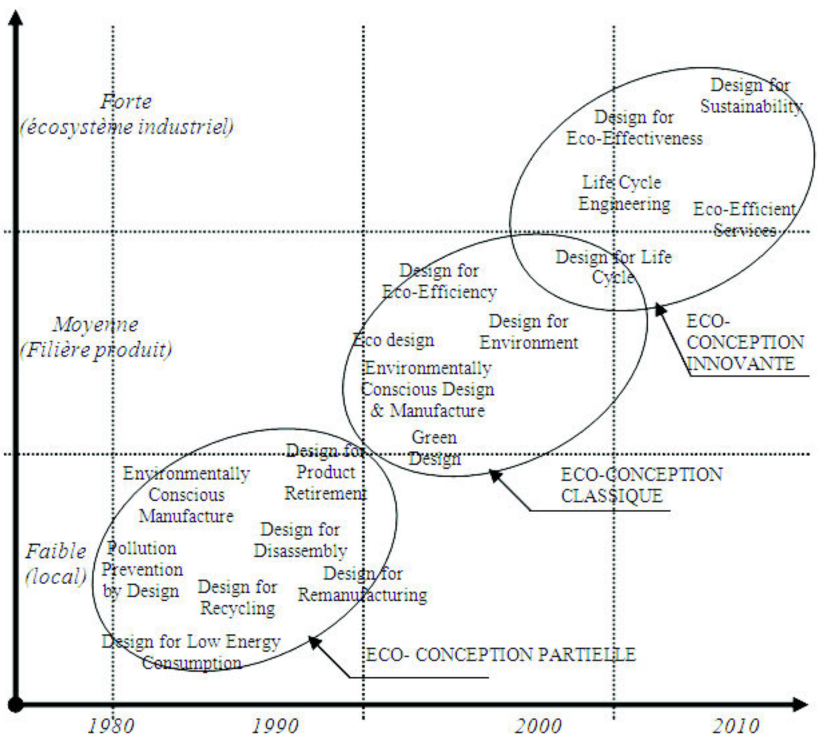


Figure 3-3: The classification of product-oriented environmental methods and tools [MILLET D., et al., 2003]

3.1.2 Design for X

“Design for X” is a wide collection of specific design guidelines or corresponding tools to modify and improve certain particular characteristics of a product or the related process in order to optimize the environment impacts. This type of eco design does not always focus on the whole life cycle of product; it contributes to the improvement in one or multi-phases (such as the “design for life cycle”). The word “X” might present variable means according to the problem treated, [Burgiel S., 2006], [Luttropp C., 2006] proposed the rules of the “black, gray and white material list” to support the material selection for reducing the use of hazardous material.[Codde, 2008] proposed a quantitative method to calculate the product’s recoverability rate in end of life phase. Even for the same topic, like “the phase of disassembly”, due to sets of characteristics which could affect the final performance, there are also a vast number of tools proposed. Some examples like [Ardente F., 2003] and [Chiodo J., 2005] analyzed sets of parameters to guides the global disassembly and recycling improvement. [Kroll E. et al., 1999] focused on the manufacturability of the disassembly process. [Kroll E. and Carver, B.S., 1999] and [Kuo T.C. 2000] calculated and evaluated the cost effects and [Desai A., 2003a,b] provides a time-based numeric indices to each design factor to determine the disassembly time of a product.

[Tatiana, 2007] indicated that “Design for X” approach is a passive solution which considers the environmental issues as a new constraint.

3.1.3 LCA - Life cycle assessment

The classic life cycle assessment is an eco-design approach which considers one or multi environmental indicators of whole life cycle during the design phase. [Reyes, 2007] indicated that this type considers environmental issues as a new product “criterion” or “characteristics”. Depending on the covered indicator’s number, [Robert K.H., 2000] separated the types as two sub-types: classic life cycle assessment and streamlined life cycle assessment.

The product-oriented LCA is a quantitative technique to analyze multi-environmental impacts associated with all the stages of a product's life cycle phase, from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling. According to the standards of ISO 14040 series, the typical analysis process of LCA includes 4 steps:

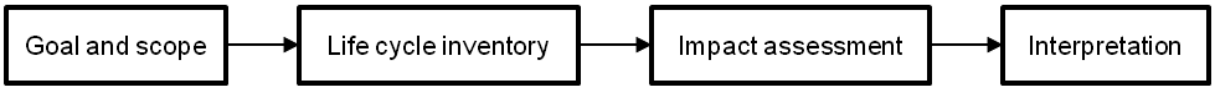


Figure 3-4: The process of product-oriented LCA

Step 1: Goal and scope: to launch a product—oriented LCA, the first step is to identify the context, scope and goal which might include these following technical details to guide the next work:

- Function unit: it defines what precisely is being studied and quantifies the service delivered by the product system, providing a reference to which the inputs and outputs can be related.
- The system boundaries: The frontier of elementary flow should be considered.
- The assumptions and limitations: The hypothesis to identify the rules of data collection and the data quality.
- The allocation methods: used to partition the environmental load of a process when several products or functions share the same process
- The impact categories chosen: The identification of environmental indicators (such as GHG, waste pollution etc.) to evaluate the environmental impacts

Step 2: Life cycle inventory, it involves creating an inventory of flows from and to nature for a product system and the functional unit defined in previous step. Inventory flows include all inputs of water, energy, and raw materials, and all releases to air, land, and water. To develop this inventory, a flow model of the technical system is constructed using data on inputs and outputs. The flow model is typically illustrated with a flow chart that includes the activities that are going to be assessed in the relevant supply chain and gives a clear picture of the technical system boundaries. The input and output data needed for the construction of the model are collected for all activities within the system boundary, including from the supply chain.

To ensure the completeness and veracity of the assessment results, the life cycle inventory with all detailed environmental related data is required.

Step 3: Inventory analysis is followed by life cycle impact assessment. This phase of LCA is aimed at evaluating the significance of potential environmental impacts based on the LCI flow results. Classical life cycle impact assessment (LCIA) consists of the selected impact categories in previous step.

Step 4: Life Cycle Interpretation is a systematic technique to identify, quantify, check, show and evaluate information from the results of the life cycle inventory and/or the life cycle impact assessment. The multi-graphic forms are support the results presentation (Matrix table, pie graph, radar graph and histogram etc.) The sensitivity, consistency check and other functions might be launched to complete the conclusion and recommendations.

ISO 14040 illustrated that this LCA approach could provide the most systemic hand holistic view of product's environmental profits which might ensure the environmental improvement without impact transfer between different indicators or between different life cycle phases.

Streamlined LCA follows the same concept of operational steps with classic LCA, but it only focuses on the evaluation and the improvement of one environmental indicator in order to simplify the complexity of data collection and calculation. The developer of such tools believes that these results could mostly approximate the results of standard LCA, because of some product's characteristics (such as the material using or the energy consumption during the whole life cycle) presents the most significant part of environmental impacts. Some common examples, such as "carbon footprint" [PAS 2050, 2008], "material flow analysis" [Ritthoff M. 2002] and the "Cumulative energy demand analysis (CED)" [Frischknecht R., 2006] pointed out this opinion. Further, [Frischknecht R., 2006] compared the environmental impacts value (presented by multi-indicators: global warming, stratospheric ozone depletion, acidification, Eutrophication, photochemical ozone formation, land use, resource depletion and human toxicity) from CED tool and standard LCA. The study results show that the CED analysis correlated well with most indicators, without waste treatment. So this is a screening impact indicator to provide an overview of global environmental performance.

3.1.4 Innovative eco design

[Wagner M., 2007] and [Millet D., 2003] indicated that in this category, the environmental characteristics have been considered as a new "value" for the product. The improvement of environmental impacts has been focused on as a "key" of development for the product and the enterprise. The innovative eco design does not analyze the used components and materials, or the entire product; it creates and develops the "new" service, functionality and concepts of offers which bring some positive influence on environment. According to [Ziegler A., 2009], there are three aspects of an environmental technological innovation. It has to be based on new technology knowledge, it must have been already implemented (i.e. new products must have been introduced on the market or new processes must have been introduced in the firm), and it only has to be new for the firm itself, not necessarily for the market. The “Sustainable product Design” is an example of the eco-tools for this area.

The detailed analysis of existing product-oriented environmental methods and tools has been attached in the Annex.

3.2 Organization-oriented environmental management

The process-oriented EMS - environmental management system is defined as “programs, codes, agreements, and commitments” that allow the organization to manage and resolve the environmental problems and reduce the related environmental impacts of manufacturing facilities [Ziegler A., 2009], [Darnall, N., 2008]. The application of EMS could gain both the environmental and cost saving performance. [Lo K.Y, 2012] analyzed the financial performance in fashion and textiles industries. The results show that beside of environmental gains, the direct operational cost and some indirect potential risk could be synchronously reduced. The law and local environmental requirements play an important role for pushing the industry moving forward to sustainability. Besides of the mandatory part, depending on the stakeholder involved into the program, the voluntary environmental program (VEP) could be classified into three different forms: the public VEPs, the negotiated agreements between companies or business associations and government and the unilateral initiatives by company [Koehler D.A., 2007], [Ziegler A., 2009].

The public VEP is charged by the government’s environmental bodies which invite certain companies to meet some particular standards or implement some new green technologies. The contents, forms, process and the criteria of evaluation are dependent on the context and objectives of each project. [Ziegler A., 2009] pointed out the most common public VEP is program “33/50” which is piloted by U.S. EPA[19] in 1991 and it aim at reducing aggregate emissions of 17 chemicals.

ISO standard series, such as the [ISO 14001, 2004], [ISO 14011, 1996] play the most important role for corporate unilateral initiatives. This organization has established standards for EMS that must be adopted for a certification according to ISO 14001, i.e. a facility must undertake an initial comprehensive review of its practices and operational systems, formulate

19 U.S. EPA: Environmental Protection Agency of Unites of States.

and implement an action plan for environmental management, identify internal governance responsibilities for environmental issues, and have a plan to correct environmental problems [Ziegler A., 2009].

Beside of ISO standards, the European "environmental management and audit system" [EMAS, 2001] directive, British standard BS7750 [BS7750, 1994] and Canadian "Responsible Care" are also often mentioned and considered in certain geographical area. These above four standards require manufacturing facilities to monitor, register, manage and improve all environmental related data. EMS also intends that the enterprise should set up their management organization to continuously deal with their environmental issues.

By analyzing these four above common standards, there are some similarities and differentia:

Similarities	Differences
- The same final objective: improvement of environmental performance of factories' actions - Similar structure and topics: ✓ Environmental Management System ✓ Preparatory Environmental Review ✓ Environmental Policy ✓ Organization and Personnel ✓ Environmental Effects/ Aspects ✓ Objectives and Targets ✓ Environmental Management Programs ✓ Manual and Documentation ✓ Operational Controls ✓ Records ✓ Audits ✓ Management Review ✓ Environmental Statement (EMAS only) - The documentation requirements to register all related information and decision - Three-party independent audit	- Different geometrical perimeter. - Different industrial targets ("Responsible Care" focuses on chemical industry) - ISO 14001 can be used in all types of organization, but three others are just for industry or factory. - EMAS and BS 7750 is a legislation which defines the environmental improvement targets, relate indicators and the guidelines. But ISO 14001 emphasizes the regulation of documentation and the management system. - EMAS require the environmental declaration and statement for all special indicators.

Table 3-1: Comparison between different environmental management systems

According to "ISO 14001" standard, the working process of environmental management system is based on "PDCA" approach:

- Plan: establish the objectives and processes necessary to deliver environmental improvement results in accordance with the organization's environmental policy.

- Do: implement the processes.
- Check: monitor and measure processes against environmental policy, objectives, targets, legal and other requirements defined in “plan” phase, and register and report the results.
- Act: take actions to continually improve performance of the environmental management system.

In the “plan” phase of ISO 14001, the initial review or gap analysis is recommended. This analysis focuses on the actual situation of the facilities used and all related elements of operational processes (the inputs / outputs / discharges and noise, dust, heart and VOC, etc) which might interact with the environment [Martin R., 1998]. According to this review, two categories of actions could be launched [Tibor, 1996]: the “improvement of global environmental performance” and “the improvement of certain corporate processes”. The global environmental performance focuses on the evaluative results of certain common impacts which are related with whole corporate process such as the material flow, the total consumption of energy and related GHG[20] emission, and the platform of waste treatment, etc. Regarding to these process, The IPPC European Directive 96/61/EC requires considering in particular a sets of environmental targets, giving regard to the likely costs and advantages of measures and to the principles of precaution and prevention.

But in order to implement these environmental targets, [Ziegler A., 2009] indicated that there is not a standard and single executable implementing manner. According to the different corporate context, the manner and the improving plan need to be adapted with certain corporate processes.

In order to initiate the reversal-loop supply chain, [Ilgin M.A., 2010] indicated that the “supply network design” is a key work to ensure the efficiency of the collection, stocking and transportation. He classified the network design model into two types, the “deterministic model” which considers only the organization of the reverse flow network and the “stochastic model” which involves also the high-degree of uncertainty associated with quality and quantity of returns. In this phase, the traditional supply chain theories and related factors are used. The operational cost, delivery timing and the delay management are focused on, and related issues, such as the number and the location of the collective points, distributor and refurbishing center, the planning and the scenarios of the transportation and the necessary stock of collected products are analyzed and optimized.

[20] GHG: Green House Gas is a gas in an atmosphere that absorbs and emits radiation within the thermal infrared range. This process is the fundamental cause of the greenhouse effect [IPCC, 2008]

Furthermore, for improving again the efficiency of the reversal-loop supply chain, the "product design" and the "predefinition of end of life treatment scenario" have a strong impact for final performance. [Ilgin M.A., 2010] summarized 29 tools and , [Veerakamolmal, P., 1999] and [Pochampally, K.K., 2009] proposed the model and cost benefit functions to guide the selection of the best product for reprocessing from this set of candidates.

Due to the differences between the reverse and forward flows in terms of the cost and complexity, the reversal-loop operations might be outsourced by third party logistics providers or directly by the end of life treatment center [Efendigil T., 2008], [Meade L., 2002]. Facing this type of method, the selection of suitable recycler is seen more important. In order to make the decision of the third party provider's selection, the multi-criteria methodology is necessary which analyze the compliance of technical quality and the operational financial performances. It's noticed that these evaluations might be integrated into the traditional supplier evaluation process and collaborates with product designer [Efendigil T., 2008], [Meade L., 2002].

Even the reversal-loop operations have been outsourced, a business-based method - "specific collaboration with recycler" is proposed in order to optimize the product's end of life performance. This collaboration requires the company to directly contact the recycler, shares the end of life treatment information, the professional experiences and the opportunities for improvement. [Korean Electronic Association, 2008] and [IEMS, 2001] provides the general framework for bidirectional recycling information sharing between the manufacturer and recyclers. This sharing system can support the raising of product's recyclability by the improvement both in design phase and recycling phase.

3.3 Conclusion

The industry is facing the challenge of the environmental consideration. This chapter summarized the numerous environmental methods and tools to answer the diversity of corporate strategies and dynamic environmental requirements. In order to be adapted to different behaviors, these existing tools are classified into two main axes: the product-oriented approach and the site-oriented approach. For each approach, there are several sub-categories. Practically, even for the same environmental objective, the required competences and resources of each set of tools are never uniform. Meanwhile, the implementation of thus tools needs to be adapted to the corporate responsibility, the state of the operational resources and knowledge and the coherence with other needs. Consequently, the growing number of environmental methods and tools and the complexity of corporate contexts are leading to a new challenge: depending on the corporate policy and the different contexts: **how can we select and organize the deployment of suitable environmental methods and tools to build the sustainability of companies?**

II

PROBLEMATIC

The words "Environment" or "sustainability" are too abstract. It's necessary to broke them down into concrete categories or attributes that can be understood, quantified and addressed. Facing to the diversity of environmental drivers and a vast number of environmental methods, it's necessary to analyze the model to identify the suitable environmental planning and integrating of the required activities into the company. Firstly, by the analysis of existing environmental methods and tools, this part indicates that the environmental methods are not independent; furthermore, there are also the interactions between different methods, especially, between the product-oriented methods and site-oriented methods. Secondly, this part explains that the selection of suitable environmental methods is necessary to consider i) these interactional effects among the environmental methods (this effect appears both for the interactions between the selected methods and the implemented ones, and the interactions among the environmental methods to be selected); ii) the dynamic corporate environmental targets and operational context which are modifiable by the interactions; iii) hierarchical organization, the responsibilities of each corporate functions and the working flow among them. Finally, this part concludes that a systemic model to evaluate and resolve this above problematic could accelerate the integration of environmental aspects into the company.

Chapter 4 - Need for considering the dynamic “complexity” to implement environmental methods

With the contribution of active scientific studies and worldwide promotion, “environmental-friendly” concept has been gradually understood and accepted by the public. In order to treat about this topic and integrate the related activities into daily work of company, as the presentation of previous part, a vast number of environmental methods have been developed [Baumann H., 2002], [Brezet P., 1997], [Unger N. et al., 2008], [Siegenthaler C.P., 2005] and [Hallstedt S., 2010] (refer to the detail presentation into Annex). The growing number of environmental methods and the complexity of corporate contexts are leading to a new challenge: *depending on the corporate policy and the different contexts, how can we select and organize the deployment of suitable environmental methods to build the sustainability of companies?*

4.1 Existing classification and evaluation approaches to select environmental methods

In order to support the decision about the suitable environmental methods for company, some classifications and evaluations approaches have been developed.

[Janin M., 2000] and [Wong, Y.L., 2009] defined the environmental methods in two principal categories by its functional propositions:

- The methods to evaluate the environmental performance

  According to [Wong, Y.L., 2009], this category includes the two sub-groups: The life cycle assessment could also be further separated as quantitative LCA, the semi-quantitative LCA and matrix LCA. The matrix LCA, named also as the qualitative LCA, evaluates the product’s life cycle by a set of ordinal scales (High-Medium-Low scales). The environmental aspects assessment includes four sub-categories: the Matrix, the checklist, the guideline for certain environmental impacts, the spider diagrams and the parametric methods.

- The methods to support the optimization of environmental design

[Janin M., 2000] defined that some norms, checklist, guidelines and software could support the eco-design. [Wong, Y.L., 2009] and [Baumann et al., 2002] pointed out also same supporting tools, such as the Environmental FMEA, Environmental QFD, that have been proposed to prioritize the environmental impacts and ensure the generation of environmental objectives.

By analyzing around 150 environmental tools about the engineering perspectives, [Baumann H. et al., 2002] summarized five categories of tools for Environmental Product Development:

- Framework: supply the general environmental ideas to support the environmental consideration. This type of environmental method includes the basic conception about what is environment, ecology or sustainability, the global framework and some original environmental proposition. The "design for X" is embedded into this category.
- Check list and guidelines: check list is a qualitative or semi-quantitative nature method to evaluate the achievement of pre-defined environmental objectives. According to the operating area, the checklist might support the qualitative life cycle assessment or only focus on one indicator or some environmental impacts in one life cycle phase. Guideline is a widely used tool to guide the users to adapt the product to environmental demands and address the environmental targets to improve. The guideline is different with checklist. The guideline provides the environmental expertise to guide the tendency and solution to improve the environmental problems which have been previously identified by the checklist. And also, the guideline might provide the necessary information to prepare the checklist, such as a checklist requires the free of the "black and gray list" material which is furnished by the guideline "Black, white and gray material list", etc.
- Rating & Ranking tools: [Baumann et al., 2002] used this "rating & Ranking tools" to name the matrix qualitative evaluation methods. This type of method provides the pre-specified environmental impacts list and a related rating method to qualitatively evaluate thus impacts (Ex: noted as 0-4, from terrible impacts to most environmental friendly). This type of method might cover the whole life cycle of product (Matrix LCA) and multi-criteria (Ex: Matrix MET - material, energy and toxicity) or only analyze the environmental performance in one life cycle phase.
- Analytical tools: The typical tool is LCA. It's a quantitative and comprehensible type of method to evaluate the environmental performance. The analytical tool treats the needs of "combination" which requires a balance and harmonization between the environmental performance and other technical/financial performances.

- Software/Expert system: The method provides the environmental expertise and all necessary information to support the product design

Facing the various number of existing methods and tools,[Unger et al, 2008] and [Mathieux et al., 2001] stand out the importance to identify the relevant criteria that choose the suitable methods for the desired objective. [Finnveden G. and Moberg A., 2005] summarized that two key criteria for selecting the suitable environmental method are "objective of the study" and "the impact of interest". They suggested also the "manner to use the tool" is an indirect factor which influences the final selection.

Based on this research, [Unger N., et al., 2008] pointed out that the choice of a suitable environmental method and consequently also the choice of suitable measures depends on five criteria: the purpose of assessment, the scope of the tool[21], the resources of the assessment, the time frame and the availability of required data. [EPA, 2001], presented similarly that the scope of tools, the time frame, the resources and the manners used to measure the results, are some keys to evaluate the candidate list of methods.

In order to identify how the environmental methods can be determined as compatible with the product development process, [Knight P. et al., 2009] referred with [Lindahl M., 2005] and [Adams G., 2006] identified eight questions to evaluate the methods to support the decision. These questions address if the methods could meet the product requirements (global requirements from the marketing and legislation requirements), if the methods could reduce the risk or save the time, and if the tools is user friendly (it is affordable, it could be used by normal staff and it's easy to adopt and implement).

In order to identify the environmental methods and integrate those in the daily development process, [Bovea M.D., 2012] evaluated the environmental methods by some common criteria:

- The contribution area: the environmental tools contribute to the life cycle analysis (completed version or simplified version), the life cycle inventory or the environmental indicator analysis.
- The product requirements: such as the customer satisfaction, technical improvement, cost analysis, or legal compliance etc.

[21] Here, [Unger N., et al., 2008] defined that the scope of assessment includes three means: the life cycle scope (this study covers the whole life cycle or only focuses on one step), the environmental indicators (the multi-indicators or single-indicator) and the stakeholders (this assessment only focuses on the functions inside of company or covers some external stakeholders).

- Nature of methods: this criterion describes if the methods are developed based on a methodology, Design supporting, Matrix, or TRIZ, etc.
- The life cycle perspective: Does this method respect the life cycle perspective
- The involved design process stages: there are five stages proposed: the function definition, the requirement definition; the alternative generation, the alternative evaluation and selection of the best alternatives.
- The nature of the results: either quantitative or qualitative

Meanwhile, [Bovea M.D., 2012] provided a list of application cases in electric and electronic domain to guide the selection. [Pardo R. J H., 2011] provides a case-based evaluation system to make the selection. By analyzing certain success industrial practices (26 projects) which are considered as references, the authors presumed that if the new case is similar with an implemented reference, the methods used in the reference might be considered as a correct suggestion. Meanwhile, if the used methods are not really available or implementable for this new case, this system could propose a similar method to replace them. Following this logic, [Pardo R. J H., 2011] identified a list of criteria to classify the implemented references and the used methods.

The criteria to identify the implemented references:

- The project objective: No redesign (The evaluation and comparison) or redesign
- The innovation level achieved (partial, functional, product, system and service etc.)
- The involved design process
- The strategies/corporate requirements (environmental impacts etc.)
- The industrial sector (EEE, automobile, etc.)
- The required information
- The life time of product

And the criteria to identify the methods

- The type of tool (Analytical, Guide and information)
- Life cycle analysis or unify-step (Life cycle perspective or the impact in single phase)
- The main function (LCA, simplified LCA, LCI – inventory, LCC-costing, LCWE-work Environment, Eco-design and product evaluation)
- The output (Qualitative/Quantitative)
- The complexity (required information, the experience needed etc.) Complexity is related to the resources required to use the tool: amount of time, amount of input information and level of expertise required. In this definition, the “complexity” of environmental method is classified into three levels [Unger N. et al., 2008], [Pardo R. J H., 2011] and [Lee, K. M. and Park, P. J., 2005]:

- ✓ High level of complexity (A): the environmental method requires a high level of information to work properly and high levels of time to be operated. Consequently, experts can only operate them because they need previous knowledge and practice. The typical methods are LCA and environmental management system. The output from such complex tools is complete quantitative models that include environmental impacts, eco-balances and costs and the possibility for conducting sensitivity analyses. They call for systemic visions and mathematical interpretations;
- ✓ Medium level of complexity (B): Compared to the methods into category A, these environmental methods are generally easy to use. They need less information and time to produce usable results. The output data can be both quantitative and qualitative, but the quantitative information is less complete and more aggregated than in the eco-tools of category A. This is mainly due to the assumptions that are quite rough but accurate enough to provide discrimination. This category includes Eco-indicator methods, Life Cycle Inventory tools, Life Cycle Costing software and some eco-design pilots.
- ✓ Low level of complexity (C). These eco-tools are intended for quick and easy use and do not require previous knowledge for their use. These eco-tools are very useful in creative meetings where engineers and designers need quick environmental product profiles, without too many details, to evaluate a concept or to explain a particular point. This category includes eco-tools such as eco-design wheels, databases and some design frameworks.

The above researches established a set of criteria to choose the available environmental methods to resolve the corporate problems. Some technical characteristics, such as the type, the purpose and the main functions of methods, could be considered as a set of key points.

But, practically, the "availability" is not equal to the "adaptability". An environmental method that operates very well in a company doesn't mean that it's great also in another company. This is due to the fact that corporate objectives and context is not similar [Unger N., 2008], [Waage S.A, 2007]. The corporate objective plays an important role to reflect the final performance of eco-innovations [Carrillo-Hermosilla J. et al., 2010]. By analyzing five selected case, they summarized that the market acceptance, the corporate policy, the implementing time and the geometrical regions are principal issues reflect the selection.

The Integrated Environmental Management System, published by US Environment Protection Agency (EPA), emphasizes that in the current corporate context, factors such as implementing cost, required time and competences of environmental method need to be considered. So the analysis of operational "effectiveness" of each environmental method plays an important role to make the selective decision [Baumann H., et al., 2002], [Unger N., 2008], [Waage S.A., 2007].

Some researchers have considered this "effectiveness" and provided several criteria to evaluate it. [Knight P. et al., 2009] identified the factor "user friendly" which evaluates if this method could be easily used in the company. [Pardo R. J H., 2011] referred to the conception of [Unger N., 2008] to summarize the operational effectiveness as a static factor "complexity" which is defined as the amount of required time and information to implement the methods. Meanwhile, there are three hierarchal levels which have been pre-identified to make the order: high, medium and low level of complexity.

4.2 Need for a systemic and holistic point of view to select the suitable environmental methods

As summarized in the above paragraphs, some researches provide a "pure" analysis to make the selective-decision on environmental methods or tools. Here, "pure" means that these approaches focus on the self-natures (technical purpose, contributive area, time frame and cost required) of environmental methods and make a hierarchical note (low/medium/high) for each method. Finally, this note could be considered as a reference for all companies.

But, practically, unlike with the static technical criteria, the operational indicators, such as cost, time frame, complexity, are dynamically changeable. According to the different corporate context and cultures, for two different companies, the characteristics of "complexity" of one method must not always be static. The typical example is from the analysis of environmental consideration into the SME. When compared with larger businesses, SMEs generally do not have dominant market positions; they have less well-defined management structures; they have no support from a parent company; they generate less environmental data; they have less environmental expertise and fewer financial and technical resources available to pursue environmental management; and they tend to have less interaction with regulatory agencies [Hillary R., 1999], [Coglianese C. and Nash J., 2002]. Due to these above barriers about the motivation, the technical support and resources, the implementation of same environmental methods in SME is more "complex" than in the large-sized company.

Meanwhile, even for two grand organizations, the different corporate knowledge structure and working habits lead also to different definition of the "complexity" for each method.

A large-sized company keeps a more complex organizational structure. The internal collaborative manner and channel require an adaptive stage in order to create the interface between the selected environmental methods and the corporate daily process.

[Donnelly K., et al., 2006] indicated that the planning of environmental management is necessary to consider all circulatory points (by the establishment of structure and responsibility) between the environmental activities and the other corporate functions. Several literatures about "POEMS" [22] support this opinion that the holistic view of environmental collaboration of each activity is necessary to be explained and organized in the planning stage [Jorgensen T.H. 2008], [De Bakker F.G.A, et al., 2002], [Erlandsson J., and Tillman A.M., 2009] and [Wagner M., 2007].

[Knight P., and Jenkins J.O., 2009] pointed out that it's necessary to take a deeper configuration to make the "compatibility" between the all contents proposed by methods and the real corporate context. By the examples of the application of the checklist, guidelines and Matrix life cycle analysis in different companies, they explains that 1) The success of "compatibility" ensure the success of the integration of environmental aspects; 2) For each type of environmental method, it's necessary to modify the contents, the interface for data exchange of the theoretical process; 3) the complexity of this stage is according to the corporate knowledge status and the compatibility between the requirements from methods and the real working process.

[EPA, 2001] illustrated that the informational circulation among all related stakeholders (internal/external) should be carefully identified, organized, reviewed and upgraded for each step and activity for meeting the environmental targets. The "circulation" does not only treat the organizational structure of the informational and decisional flow (such as the forma and the typical content of data, the moment, manner and process of data exchange and the systemic IT system), it also needs to consider the abilities of data exchange. Globally, the company is required to make the corporate policy communication. And locally, for each step or activity, the company needs to organize cognition training about daily activities, develop the competence for dealing with the data, and manage the individual development for using the related tools. In order to release these works, [EPA, 2001] suggested a systemic and

[22] POEMS: Product-oriented environmental management system, is a systemic approach to take the product's life cycle analysis and management by the existing concept of environmental management system

holistic overview of all related environmental steps or activity which have been required by the implemented environmental targets or methods, while they are in the planning stage.

As a summary, the dynamic answer of the available corporate resources and the real inter-operability between environmental activities and other working process require the analysis of the method’s compatibility. It could not only be analyzed by the “pure” analysis of environmental method. In order to make a suitable selection, it’s necessary to create a model to integrate systemically the influences from the dynamic corporate operational environment. The above paragraphs present that it’s necessary to consider the dynamic context to make the method’s selection. But this discussion only focuses on the influence of initial operational context. In fact, through the implementation of the environmental program, this operational context of each company, such as the competences and the knowledge status, etc. is also changeable. Does this changeability affect the methods selection? The next two sections (4.3 and 4.4) will explain two different types of influence from the dynamic operational context. Sector 4.3 presents the previous environmental program which could continuously modify the context. And sector 4.4 presents the influences from the parallel implementing programs.

4.3 Need to consider previous steps at the beginning of program organization

The previous and current implemented environmental methods could influence the selection of a new one, because they have modified the corporate context concerning the environmental consideration, such as the competences and know-how, the expertise and the informatics database. [Pardo R. et al., 2011] indicated that an adaptive selection for suitable methods is very important, not only to assure the suitability, but also to harmonize the previous projects and allow inheriting the gained knowledge.

[Zhang F., et al. 2013] illustrated this point by an example. The analysis result of the product “recyclability” is a pre-condition for launching the product’s “end-of-life improvement”. If “end of life improvement” is one of the final corporate strategic objectives, the evaluation of the “recyclability” of the current product might be a stage in preparing this condition. So the “complexity” definition of “end of life improvement” methods should consider how this previous stage has been done.

Oppositely, when the actual corporate context is insufficient to implement a final environmental method which requires multiple previous activities, therefore a new challenge for environmental method selection would appear: *how can the company have the capacity to continually modify the selecting conditions to prepare a long-term implementation plan in its early stage which identifies a trajectory of achievement with a series of environmental methods, step by step?*

Each step could be considered as a series of "enabling goals" which is a special type of shorter-term goal. Enabling goals are written to achieve, measure the progress toward reaching the long-term goal. Globally, starting with the analysis of the actual resource (material/immaterial) and the operational constraints of company, the identification of all short term programs requires also the harmonization with the corporate developing tendency and the related competence development planning.

At first, due to the large number of environmental methods which have been developed, there are different trajectories (which require different groups of previous actions or short term programs). The following literatures about the "EMS - Environmental Management System" provide an example. [ISO 14001, 2004] and European standard [EMAS, 2001], set up two similar framework to integrate the EMS into the company. The company could refer the local regional and corporate environmental policy and some initiatives to identify the topics to improve. Due to the fact that different types of topics require different resources and different pre-actions, the selection of EMS as the corporate actionable plan could not only focus on the EMS-itself (the necessary actions and documentation system required by ISO 14001 or EMAS), it's necessary to make a holistic analysis with all different options. [Zhang F. and Zwolinski P., 2012] and [Zhang F. et al., 2013] summarized that the corporate environmental management system could focus on either the life cycle consideration, or certain specific environmental topics, or both of them (the identification of the environmental topics depends on the corporate policy, the gap between the legislative requirements and corporate states, the results of environmental audits and customers needs). For contributing the life cycle consideration, the company might consider a single environmental indicator (the material flow, the energy footprint or the carbon footprint, etc.) or multiple indicators. Additional, the cost analysis of each possible option to resolve the environmental topics could be integrated also to make the balance between the economic and ecologic objectives. Finally, In order to improve the profits of certain environmental topics, the company might refer the BATs[23], the

[23] BAT : Best Available Technology - The term constitutes a moving target on practices, since developing societal values and advancing techniques may change what is currently regarded as "reasonably achievable", "best practicable" and "best available".

external requirements form the laws and customer’s need. It also could refer the related product-oriented LCA and certain environmental improvements.

From the above summary of literatures, several options or pre-actions (such as the database and the LCA of related product) are considered as the different branches of the EMS. For completing the EMS, one of these branches is obligatory to be selected. So in order to evaluate the “complexity” of EMS, at first it’s necessary to explore how many trajectories are available and what they require for implementing themselves. Finally, a holistic view (including the EMS itself and all available options) should be focused on to make a final selection.

4.4 Need to consider the collaboration among different methods

The “environmental” issue is not an independent issue for a company. It’s necessary to evaluate the systemic relationship among the different environmental activities.

Meanwhile, in practice, facing the multi-requirements from the environmental laws and customers, the company needs to deal with several strategic objectives and launch several related eco activities at the same time. [Zhang F. and Zwolinski P., 2011] and [Reyes T., 2008] presented the same points through an industrial review of the corporate eco-design program. According to [Blessing L. T., 2009], the design is particularly complex process, involving and organizing the different types of human resource or stakeholders (such as the product designers, external experts, suppliers etc.), processing, activities, procedures, knowledge, tools and methods. Each step of design process, from product planning, specification of product’s development, conceptual design to detailed design, requires different tasks which need the support from different engineering methods and tools [Pahl G., 1996]. And the environmental method and tool are a part of the necessary tool kits. However, according to [ISO Standard 14062: 2002], it defines the “process” as a unit of correlated or interactive activities which transforms elements of input into elements of output.

This practical need leads to an additional challenge regarding the dynamic selection of environmental methods. *How to optimize the environmental methods network in the company?* In other words, *how implementable methods affect the dynamic operational context when selecting another parallel method?*

In order to explain the "interoperability[24]" among different environmental tools along the design process, [Rio M., 2011[a,b]] defined a "local and global tools framework".

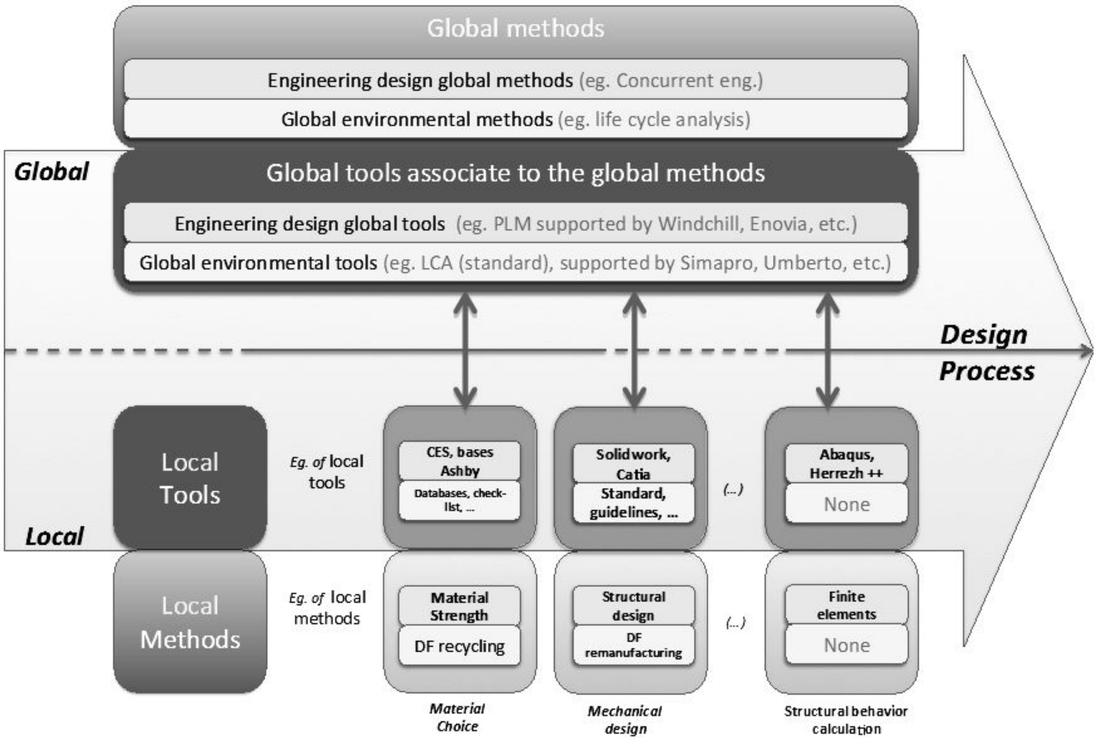


Figure 4-1: Local and global organizational framework: a distinction between local products designers' activities and global environmental activity (transversal) [Rio M., 2011[a,b]]

- Global methods, such as the life cycle analysis, are based on a transversal vision. These methods require a global and transversal vision in order to deal with the "collateral impacts" of the various targets taken separately from different domains (such as structural design choice, mechanical choice and material choice). In order to resolve multiple impacts and targets, it's necessary to regroup several environmental "actions" which are supported by a wide variety of tools.
- Local methods are managed by identified and separate product design activities. "Design for X" methods for instance, are local methods. "X" refers to the specific local activity involved, supported by specific tools (such as CAD software for mechanical design activity for instance).

As shown in Figure 4.1, this framework is ranking several local and global environmental (transversal) tools, supporting different "actions" along the design process. In addition, this framework supports the identification of local and global links between the environmental

[24] Interoperability is the capacity of two or more actions to exchange information by the software or tools

tools needed to support collaboration from the beginning until the end of the design process (symbolized by the arrows).

However in practice, [Rio M., 2011[a,b]] emphasized that these links are difficult to be established. [Vallet F. et al. 2000] pointed out that the environmental cognitive is a barrier to encourage the interoperation. [Riel A. et al., 2010], and [Niemann J. et al., 2009] highlighted the difficulty in sharing knowledge and data related to different domain activity. [Paviot T., 2010] summarized that the dynamic context of design process (different product types, different corporate culture and customs, the different corporate function and designing process) make difficult interoperation among different environmental methods. [Knight P. and Jenkins J.O., 2009] pointed out also that the pre-formulated methods are not necessarily generic and immediately applicable, but instead require some form of process-specific customization prior to use. The main raison is lack of the contribution from the industrial user during the method's developing phase [Baumann H., 2002]. The developer only focuses on the functional achievement of the proposed method, takes less attention into the adaptability of certain functions into the real industrial dynamic context.

In order to resolve this problem, [Knight P. and Jenkins J.O., 2009] suggest to develop an "applicability framework" to recognize, modify and develop some environmental methods. This framework takes a systemic evaluation about three selected environmental method, environmental checklist, the guideline and the MET matrix. Basing the combination with the corporate objective, he provides a global integration plan to optimize the applicability of these three tools. Knight provides an example of implementing the selected methods, but he did not provide any suggestion about how to affect the method selection by the interactions among environmental methods. [Iraqi M., et al., 2011] argues that interoperability supported by federative approaches provides more flexibility. Federation is based on a unique meta-meta-model. It means that any new model can be added by dynamic adjustment which makes it suitable for linking local and global environmental tools. [Mathieux F. et al., 2007] using federation, compare the efficiency of CAD data transfer into LCA tools, to PLM data transfer solutions. The authors argue that federation could improve cooperation between product designers and environmental engineers.

According to the lack of related researches on systematic relationships among the eco activities in enterprise, [Zhang F. and Zwolinski P., 2012] proposed that the identification of an environmental-methods group should consider three coherences:

- coordination with the corporate global direction, which might include corporate definition of “Eco design” and the related competence and source development situation, etc.;
- cooperation with other corporate functions considering their complex context;
- cooperation with other executing eco design methods and related process to treat about several issues at the same time;

Focusing on methods, the coherence requires two types of analysis: first, an analysis of the “participatory” and “co-operability” of required information and resources among all pre-selected environmental methods. “Participatory” means that several resources can be used by different methods, and “co-operability” presents the operational chain of the methods, so that the outputs of some environmental activities can be used as the inputs of others. This analysis could dynamically evaluate the operational complexity of different method groups, because the context and condition have been changed by an already-implemented method. Secondly, this analysis focuses on “trade-off” risks which can be a source of confusion between the environmental targets [Zhang F. and Zwolinski P., 2012], [Byggeth S. and Hochschorner E., 2006]. A dynamic analysis should be launched to evaluate whether the selected methods could lead to this risk.

4.5 Conclusion about the selection of methods: need to consider the “dynamic complexity” of environmental integration

According to the previous illustration, a pure analysis of the “complexity” of an environmental method, without analyzing the operating environment, is not enough to guide the company’s selection. [Byggeth et al, 2007] argue that one problem with the tools developed to consider and integrate the environmental aspect is that these methods are disconnected from the real dynamic of corporate context. [Zhang F. and Zwolinski P., 2011] pointed out that it’s necessary to identify a continuous monitoring system to make a dynamic analysis of the corporate context. Meanwhile, [Unger N., 2008] and [Kengpol A. and Boonkanit P., 2011] claimed that there is no uniform solution to select environmental methods. Also, Unger indicated that the possible factors to take into account to select an eco-tool, such as the time frame or the resources available is necessary to relate with the project context. [Waage S.A, 2007] identified a lack of prioritization of supports for defining the sustainable aspects of each context and selecting suitable actions. More specifically, facing the requirements from the identification of a global step by step program, and the requirements about the "multi-objectives optimization", there is a lack of evaluative method that could provide this systemic view on the relationship among the different environmental method (series and parallel) and provide a robust mechanism to identify make a holistic and systemic decision [25][Zhang F. et al., 2013], [Reyes T., 2007]. This "holistic and systemic decision" means that this available program can handle and treat the relationships among multiple targets simultaneously in the transverse direction ("participatory", "co-operability" and "trade-off" risks), and in longitudinal direction (focus on the implementing steps for resolving the final objective).

[25]In this research, "Holistic" means that the approach is part of a global meta-system and is not disconnected from its contexts (economic, political, environmental and social), sources flows (material and immaterial) and reservoirs of value (such as people, knowledge, process). "Systemic" means that every node of the system supports dynamic interactions with the whole system [Mercier-Laurent E., 2011].

Chapter 5 - Needs to consider uniform environmental activities into company

From the previous section 4.3, we find out that in order to improve the integration of environmental aspects, it's necessary to consider the coherence among different methods during the design process. This chapter will continue to discuss this problem in a larger "system boundary" which takes the environmental management process into account. Here, this "system boundary" includes two main approaches to consider the environmental aspects: the site-oriented approach and the product-oriented approach.

1. ***The site-oriented approach*** focuses on company's own environmental impacts according to the input/output flow, which includes the material/energy imported and used, the emission and waste generated and the stocking activities, inside of the organizational boundary. The Impact factors can be classified into three categories:

- Depletion of un-renewable or renewable resources (in the form of material or energy)
- Pollutions: some environmental indicators might be considered, such as the greenhouse effect, the depletion of the ozone layer, the pollution and toxicity in air, soil and water.
- Disturbance: such as the land use, the climate change and the degradation of eco-system.

As mentioned earlier into the "part I", for voluntary environmental practices, the environmental management system is usually used to manage and resolve these above environmental impacts. ISO standards [ISO 14001, 2004], [ISO 14011, 1996] play the most important role in this area. The European "environmental management and audit system" [EMAS, 2001] directive, British standard BS7750 [BS7750, 1994] and Canadian "Responsible Care" are also often mentioned. These above four standards require the manufacturing facilities to monitor, register, manage and improve all environmental related data. EMS also intends that the enterprise should set up their management organization to continuously deal with their environmental issues.

2. ***The product-oriented approach*** focuses on the product's environmental aspects which might be larger than the traditional organizational boundary. Today, with the development of the life cycle consideration, the product boundary of environmental issues needs to cover the whole life cycle, from the material exploration and fabrication, production phase, using phase to the end of life phase. Other processes such as the transport, energy supply and other supporting services are commonly incorporated between the stages.

In order to improve the integration of environmental aspects, the industry is required to face the two above principal approaches at the same time. The complexity of this requirement is leading to a consideration: *Does the company need a systemic model to harmonize the development of these two approaches? If yes, how to do it?*

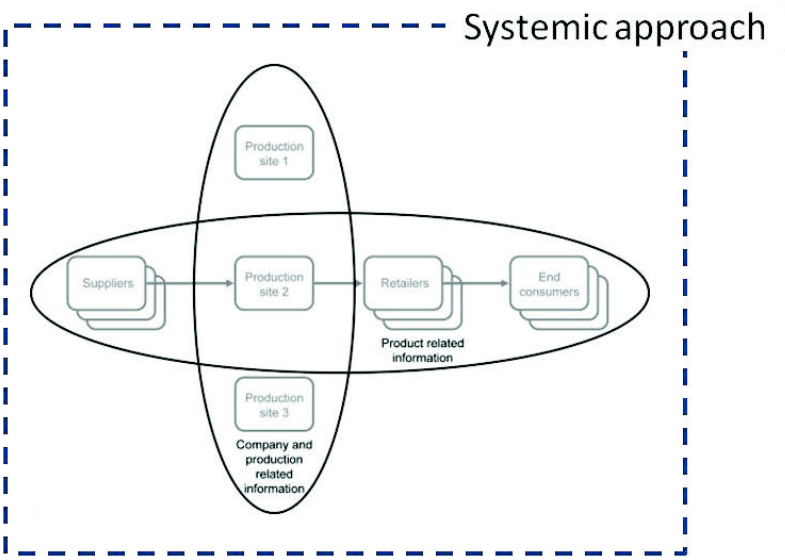


Figure 5-1: The crossing matrix about product-oriented approach and sit-oriented approach

In order to answer this question, this chapter is to analyze and clarify the relationship and some detailed interactions between these two approaches. The section 5.1, at macro level, presents the fact that these two approaches are not independent. The section 5.2, 5.3, and 5.4 classifies some environmental activities in different corporate functions (eco purchasing, eco manufacturing, and eco communication). These analyses are to indicate that the suitable identification of the “eco design” methods and tools should not only consider the technical targets and the related criteria, it has also to consider the coherence with eco activities of other corporate functions. Finally, facing these complex interactions and the lack of scientific model, paragraph 5.5 summarizes that it’s necessary to a construct a systematic model, which treats about the relationships among different eco activities and related methods on global level in order to accelerate the integration of environmental aspects into company.

5.1 Relation between the site-oriented approach and the product-oriented approach?

The product is one of the key elements of a company. The decision-making of product development is supported and improved by collection, exchange and management of information and data from both internal (e.g. manufacturing processes, service delivery) and external (e.g. customers) sources and organizations. [Erlandsson J., 2009] indicated that product-related information includes the data of enterprise's own activities, but often only a subset of them. The figure 5-1 shows the different scope of two above principal approaches.

At macro level, the environmental management with technical innovation is ambiguous and combined [Ziegler A., 2009]. Some literature indicated that there are some significant interaction effects between product and organization oriented approaches.

5.1.1 Effects of product innovation on environmental management of organization?

ISO 14062 indicated that the optimization of product's environmental impacts affects also the global performance of manufacturing site. In the standard text, two main relationships are mentioned:

- Conservation of resources, recycling and energy recovery, and
- Prevention of pollution, waste and other impacts.

This first objective is to optimize the use of resources required for product (material and energy) without having a negative effect on its using performance. Decreasing the quantity and hazardousness of materials used also can minimize the creation of waste and related treatment cost during production and disposal phase. Product design and development can incorporate features that make the product more suitable for subsequent reuse, recycling, or for use as a source of energy.

Secondly, using end-of-pipe means such as sewage treatment and incinerators can reduce pollution and other impacts generated by a product during its life cycle. But these manners cannot be the ultimate for the reduction of pollution, waste and other impacts because they can generate other pollution or waste, such as sewage sludge, ashes, slag, etc. Greater environmental improvements can be achieved by using measures that prevent pollution or other impacts. Such approaches deal with problems at their source, the product design or the tooling of production line considerably reducing the cause of the environmental impact and the cost associated with the end-of-pipe treatment.

[Ziegler A., 2009], [Wagner M., 2007] proved also that environmental management system could be affected by environmental product innovations. [Wagner M., 2007] summarized seven analysis to point out the effects of environmental product innovation on environmental management as a specific measure for environmental performance. Such environmental product focuses on more complex environmental indicators than restricted one-dimensional measures. According to this, enterprise which already realized such product specific innovations, is more likely to possess environmental capabilities in having overcome management barriers such as the lack of finance or know-how at least once before.

5.1.2 Effects of environmental management of organization on product innovation

[Ziegler A., 2004], [Ziegler A., 2009],, ISO 14001 and ISO 14062 indicated that the integration of environmental aspects into product design and development can be influenced, piloted and supported by existing environmental management, especially, the situation of the "resource" global management. Some literatures explain the relationship between products and environmental management based on this resource-based view of enterprise. In this approach, an enterprise is considered as a "bundles of resources" which is defined as all available or potential assets and capabilities [De Bakker F.G.A., 2002]. Deeply, here, the "capabilities" are defined as the ability to coordinate, deploy and legitimate the resources to perform the tasks. [Ziegler A., 2009] pointed out the importance of firms' internal capabilities or resources which are valuable, rare, and difficult to imitate or substitute. From this resource based view of the enterprise, the organization-oriented environmental management system develops and optimizes the availability of the resources (including the capital or substance inputs, the capacities and know how) which are considered as a mine of product innovation [Ziegler A., 2009], [Horbach, J., 2008] and [Rennings, K., 2006].

Meanwhile, a common strategic definition of "Green" in enterprise is considered as a key element. This definition defines the list of environmental indicators necessary and the related measuring methods. These indicators might focus on the organization activities and the product characteristics. So any improvement on organizational activities, especially, on production line affects the product's environmental performance. Inversely, the product's improvements need to consider the conditions or constraints from organizational parts.

ISO 14062 indicated also that the success of integrating environmental aspects into product design and development in an organization is enhanced by the involvement of relevant disciplines and organizational functions such as design, purchasing or supply manager, manufacturing and marketing, which have been integrated into the classic site-oriented management system.

So each function, like purchasing, production and communication, is situated in a cross-matrix, and should answer the requirements from two approaches at the same time. Beside of the design process, next sections indicate the details of the relationship and the interactions between two principal approaches in some function's (production, purchasing and marketing department). They illustrate a detailed image about the suitable identification of environmental methods should not only consider the technical targets and the related criteria of one approach, it has also to consider the coherence with the requirements from another one.

5.2 Situation of the "green purchasing" in the cross matrix to treat the interactions between two approaches

Supply chain is a system of organizations, people, technology, activities, information and resources involved in moving a product or service from supplier to customer. The green supply chain is to indicate the supply management activities that attempts to contribute to the sustainable performance of all traditional and related-extended supply activities [Beamon B.M., 1999]. Greening purchasing and supply management relies on the deployment of relevant supply management capabilities and methods. Two main strategic axes of green supply might be identified to classify them [Bowen F. et al., 2001], [Seuring and Muller, 2008]:

- Supplier management for environmental performance and risks management based on organization-oriented approach
- Supplier management for sustainable product development based on the "Product-oriented approach

5.2.1 Supplier management for environmental performance and risks management based on organization-oriented approach

To answer the external pressures, the first manner is to set up an environmental management system of supply chain on global level to avoid the environmental related risks. Together with increased outsourcing, a number of companies have introduced supplier evaluation schemes which integrate environmental criteria. This "commodity"[26] supplier management system requires some basic criteria (in accordance with the external pressures) to monitor, evaluate, report the supplier's process and its global performance [Seuring and Muller, 2008]. The "global" means that these criteria focus on the environmental performance at organizational level, such as the recording documentation of environmental data, the global waste and hazardous material controlling, without the requirements and audits on certain products or services. Finally, these environmental performances are seen as the prerequisites for suppliers which range and allow them to provide materials or service(s) to operate as part of the supply chain [Lamming RC, 1996], [Min H, 2001].

For the activities of this axis, the regulation and normal standards play an important role. They mainly focus on the certification of ISO 140001 and EMAS. To obtain these certifications, some activities, such as the monitoring of daily processes and the evaluation of supplier's environmental management system, are established. Then, the corporate private questionnaire which is sent to suppliers for self-audit - are usually mentioned [Baumann H., 2002]. This self-audit indicates how the supplier deals with environmental issues, how it collects data and declares the results. Thirdly, enterprises have to take a longer part of the supply chain into account to allow an improvement in the supply relations as well as in the performance. An enterprise-overlapping communication and a strategic training to improve the supplier's performances are usually proposed [Seuring S., 2008].

Besides of above mentioned traditional activities of supply chain, according to environmental challenges, especially, the requirements for waste "take-back system", some new extended activities are required for purchasing or supply chain management, such as the audit, verification and keeping the relationship or interactions with material recyclers or product's remanufacturers. [Beamon B.M., 1999] indicated that these activities and related material flows should be embedded as an additional resource into the purchasing management system.

[26] Commodity: means the goods or services. The commodity purchasing focuses on the deliverability of one material or service on corporate level, such as the copper, the cotton or some office issues. The deliverability of certain product or production line excludes the consideration.

5.2.2 Supplier management for sustainable product development based on the "Product-oriented approach

As the interface between the product design and the supplier, the purchasing department needs to focus on the product requirements. Basing on the environmental requirements or initiatives, the purchasing department should establish a manner to require, train and cooperate with suppliers within the framework of "life cycle thinking". The purchasing should ensure the deliverability of required supply quality. Some literatures indicated that this deliverability is a key condition to offer sustainable product. [Goldbach M., 2003] indicated that an available, stable and quality deliverability is a key condition to ensure the success of "eco design". [Kogg B., 2003] provided an example of organic cotton to explain that textile and apparel producers/retailers have to make sure there is an organic cotton supplier before they are able to offer such products.

The criteria of supplier evaluation do not only focus on the final delivers, but also include the checking points about the processing technologies and tooling. The supplier should declare or prove that they can meet all required environmental standards (the local laws and the required laws by enterprise) for the production line, as well as the final delivers.

In line with these above requirements, the cooperation with suppliers increases in importance. In supply chain management for green products, ensuring the quality of the product and the performance of the operational process might be as much of an issue as building partnerships for new product introductions, so the complete supply chain from raw materials to final customers has to be integrated [Seuring S., 2008].

Additionally, in order to keep a long term relationship with suppliers, a training and cooperation on product level are considered also as a key part. In this case, these communications not only require an exchange among supply chain on process level, but also on product level, when some deeper technical information should be translated [Handfield R., 2005].

For the activities of this axis, the LCA or LCA-related methods are usually mentioned to support the enterprise to address the eco design related issues and necessary information. The additional condition is the corporate definition of "Eco design" which pre-indicates the goal and boundaries of the cooperation. The project's buyer, delegate the project team, keeps the real contact and cooperation with suppliers to achieve specific project's goal.

5.2.3 Effects of interactions between organization and product oriented approaches

According to the above illustration, the two above strategic axes are not mutually exclusive. [Seuring S., 2008] indicated that while they seem as two different, distinguishable approaches, they also support each other at the same time.

At first, the project purchasing required the completed comprehension and the integration of strategic purchasing requirements which could be provided directly by the authorized supplier shortlist from strategic “green supply process”. Inversely, the global evaluation criteria require the product-oriented axis provides the feedback about the real environmental performance of certain production line. In order to make a significant “sustainability”, it’s also necessary to report the project’s particular needs and comments to commodity part to update the criteria of global evaluation. [Handfield R, 2005] pointed out that when the enterprise started to offer the environmental improved product in their product line, they experienced the need to monitor the environmental performance of the suppliers. Conversely, companies starting with supplier development initiatives for risk minimization might then see opportunities for further win-win-win situations, and look at product performance as well [Min H, 2001], [Cousins P.D., 2004].

In 2005, [Chen C.C., 2005] indicated that a global framework to plan the green purchasing process is necessary to be established. He provided a framework of guidelines to implement a set of practices. Referring to the similar structure of “Plan-Do-Check”, this framework provides a concise overview of the three stages requires for the implementation of green purchasing (Figure 5-2).

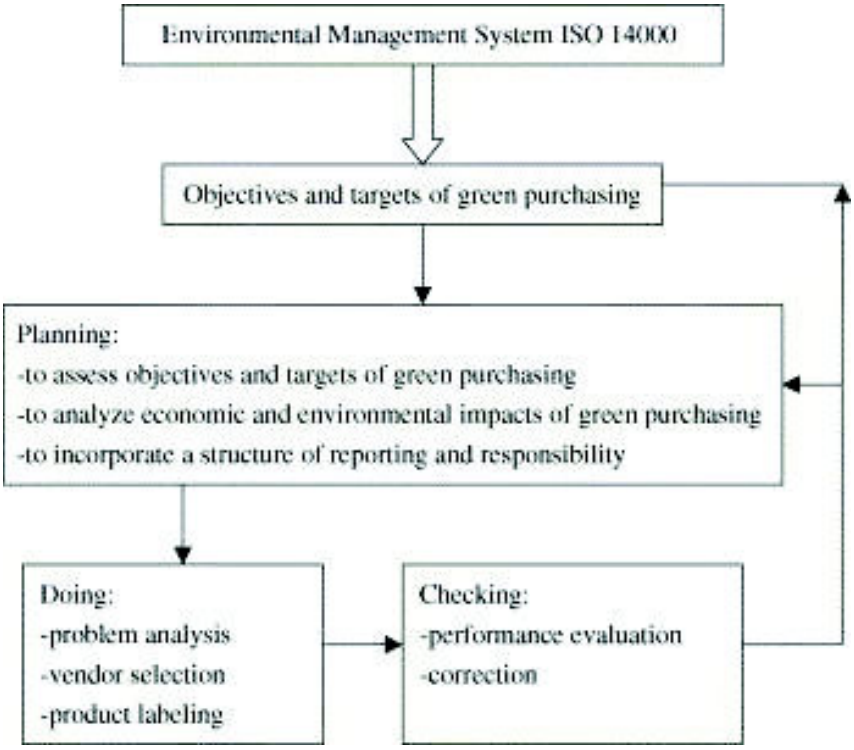


Figure 5-2: The framework to implement a practice of green purchasing [Chen C.C., 2005]

Firstly the framework requires the company to set up a clear green purchasing target to assure effective planning and implementation. Secondly, at the “planning” stage, the company needs to describe the details about its practice and measurement of green purchasing. Thus, a body of knowledge about green purchasing practices must be developed to meet the future trend through appropriate evaluation tools in order to analyze the economic and environmental impacts of green purchasing, and to evaluate the compliance with environmental policy, potentially significant environmental impacts of production process and product, business considerations and technological options, etc.

And then, at “Do” phase, the final aim is to increase purchaser's knowledge in implementing green purchasing practices and set up the management structure and the reporting system of green purchases to meet the requirements of ISO 14031. The management needs to assign environmental responsibilities to all related functions with a specified target and with a clear documentation process. Finally, an indicator system needs to be established to measure the environmental achievement of green purchasing.

This framework set up the general process of systemic green purchasing. But it did not provide the details of guidelines for how to integrate these two approaches together to construct the purchasing target and related programs. There is also lack of the detailed guideline for some significant issues, such as which indicators should be integrated and required by suppliers, the manner and the time of exchange among different external and internal functions; how to identify and balance the detailed program objectives to ensure the final achievement and finally, how to evaluate the contribution of each action. [Seuring S., 2008] indicated also till now an important barrier for implementing the green purchasing is the lack of detailed guidelines for each planning.

5.3 Situation of the environmental management of the production into the cross matrix

In the “plan” phase of ISO 14001, the initial review or gap analysis between the facilities and all the related manufacturing processes of each product is recommended. The results support the identification of all the elements of the current operations (the inputs/outputs/discharges and noise, dust, heart and VOC, etc.), which might interact with the environment [Martin R., 2000]. According to this “gap analysis”, and analyzing the industrial pratices, [Tibor, 1996] summarized two strategic axes could be launched for optimizing the environmental performances of production:

- **The improvement for global site-oriented environmental performance**

  The system boundary of analysis is focusing on the corporate level or one facility. It means that the facility is considered as a whole element, the analysis is based on the overall resource flow, including the material/energy flow, waste flow and pollution. So the improvable point is situated on the creation of manageable platform or technologies for entire facility which focuses on the material flow analysis, the stock management or the pollution monitoring system [REYES T., 2009]. The IPPC European Directive 96/61/EC requires considering in particular some significant topics, giving regard to the likely costs and advantages of measures and to the principles of precaution and prevention: such as the use of low-waste technology, less hazardous substances and furthering of recovery and recycling of substances generated and used in the process. These above topics are based on the overcome facilities level.

  Some common topics are usually mentioned as listed below:

  - Local surroundings: Compliant with regulation / the complaints from industrial zone
  - Waste : collection center / risks control / reduction program / encourage recycling
  - Water pollution : separate the rain water and waste water / interceptors, filtering recycling

- Perturbation: Measure discharge to atmosphere / Land use
- Other risks and hazards: various power usage / solvent storage

The evaluation results of above topics might cover several activities from different production line. And the improvement targets affect also the environmental performance of a product whose production line has been covered.

- **The improvement of certain manufacturing processes according to the requirement from product eco-design**

The production line situates as the crossing-point of facilities and the product design team. According to the global improvement planning and some specific requirements of production from eco design, there are certain actions which focus on the improvement of the product manufacturing process. Based on the LCA of products, the best available technologies (named as BAT below) are identified as new solutions to optimize the environmental impacts [Nieminen E. et al., 2007]. Above topics or evaluation indicators of the first axis could be used also for this improvement. But some operational topics and indicators of production process are decided by the designer [EuP directive, 2005], such as the selection of input materials, the definition of production manners and tooling, etc. So a relationship between the manufacturing faculties and eco design is necessary to accelerate this improvement. Inversely, the improvement of manufacturing process contributes also to the eco design results which are developed by design team.

Several authors indicated that there are several interactions between these two approaches. The standard ISO 14001 requires a certificated company to have an environmental management system (EMS) which covers all the significant environmental aspects or effects which the company can control or influence. Meanwhile, the company must demonstrate also an understanding of the environmental effects of its suppliers and of its products, including planned or proposed products, in use and disposal phase. But there is no requirement in ISO 14001 for detailed life cycle assessments (LCA), nor the recommendations about the eco-design integration. Professor Martin Charter[27] summarized that there are many issues related to site-oriented approach which also apply to product-oriented approach, since eco-design should consider the life cycle of a product, including its operational conditions of manufacturing. And inversely, the significant environmental aspects relate to materials or purchased product sourcing, product use and disposal. And actually, some industrial practices

[27] Charter M., Product design and ISO 14001 a guide for environmental managers & product designers, The Centre for Sustainable Design

presents that the purchasing and global improvement decision are defined at head office, and there may limit the generation of the design decision. [Zhang F., 2012] presents the similar situation that the independently improvement of the facilities performance actually makes a general constraints for each production line. This constraint is not stable. Within the deployment of BATs at facilities level, the environmental conditions are also continuously modified to influence the eco design practices. Facing this situation, Charter and Zhang suggested that in each step of environmental management system, the harmonization of these two approaches is necessary to be considered.

5.4 Situation of the environmental communication in the cross matrix

The eco communication is defined as all the communication activities, through dissemination of publications (booklets, marks, reports in all kinds of form: paper or electronic) or through the completion of events (seminars, conferences and exhibitions, etc.). It contributes significantly to various environmental improvements[28]. Those improvements might indicate the activities of enterprise, or their performances throughout the product life cycle[29].

The ecological certification of enterprise environmental performance is more and more visible. The certification report of ISO 14001 could be considered as an important example. Besides, there are other evaluation systems, which were established by some independent third party, to monitor, evaluate and support the improvement of the enterprise activities. We launched an analysis showing that from 84 found eco labeling system in textile industry, there are 31 evaluation systems focused on the environmental performance on enterprise level[30]. To obtain the certification, the enterprise might set up a set of criteria to comply with the requirements on certain activities, including engineering, purchasing, industry, etc. It's necessary to consider that those criteria might have a positive influence on the decision for the selection of the eco methods for designers.

Till now, the environmental product declaration systems had become a wide-spread method in order to fulfill the effective market communication around the eco consumption. The

[28] The guideline of "Eco communication", ADEME, 2005 http://www2.ademe.fr/servlet/KBaseShow?sort=-1&cid=22284&m=3&catid=22303

[29] "Global Eco label Monitor 2010", World Resource Institute, 2010

[30] The method of analysis is as below:
1st selection and generation of targeted eco labels: The web-based explorer "Eco labelling" has been used to find out the official website of each eco label system.
2nd Analysis of technical criteria of eco label: The analysis of the requirements of eco labelling criteria has been done. This analysis indicates the necessary industrial actions to obtain the certification of eco labelling.

voluntary Eco labeling systems presented an important role. ISO divides the environmental labeling into three categories:

Type I eco labeling was established by a third independent organization which identifies overall environmental performance of a product or service within a specific category based on life cycle considerations. The criteria of each label were set up according to the common significant environmental topics of such product/service throughout entire life cycle of product. But even for same product's category, the criteria from different labeling systems are not similar. This distinction leading to these standards cannot be used directly by the enterprise to establish uniform standards for an international market. But on project level, in order to answer the extern requirements, some criteria of certain eco labeling system might be involved into the specification of the product as a reference of development. A method which supports the project to analyze and check the compliance of the product with the criteria of eco labeling, had been developed [Houe R., 2009].

Type II and type III eco labelling allow the enterprise to self-declare their private environmental claims. Similar with type I labelling system, type II system create an endorsement marks system to have an effect on the purchasing decisions of the customers. The type III system, which provides quantified environmental data of product, is intended for B-to-B business mode. These two private systems are feasible to set a normal standard for all products on international marketing.

But, a necessary precondition of establishment of these processes is the corporate definition of "green" or "sustainable" aspects. It means that the enterprise should firstly define a list of evaluation indicators and measuring methods on global level to pilot the resolving of environmental issues. These criteria need to consider the actual organizational and product's environmental performance and the related developing plan. We believe that an interactive relationship between those two approaches (organization and product-oriented) could accelerate the improvement of the entire environmental performance for both the product and the enterprise.

5.5 Need for coherence between organization and product oriented approaches to accelerate the integration of environmental concerns in enterprise

The above paragraphs summarized the typical environmental activities for four principal functions of the enterprise – engineering or design, manufacturing, supply chain and communication. In each section, the profits and all related environmental objectives have been classified into two generic axes:

Axe 1: The eco activities which minimize the environmental impacts of enterprise

Axe 2: The eco activities which minimize the product's life cycle impacts

The activities contributing to the needs of the two above axes are not exactly independent. In fact, they are mutually constrained, and sometimes, they are mutually supported. As above mentioned, the identification of the environmental activities to answer one axe's needs, should consider the constraints from another one. From above paragraphs, the interactions appear from the resource level, which includes all material resource (Substance imported, available energy support, etc.) and immaterial resources (competence and know-how, etc.).

For example, the global material flow controlling defines the availability of material/ substances types. The "eco-design" activities should continuously consider the development of this constraint and look for the suitable designing options. Inversely, in order to avoid the "incompatible" risk, the global material flow controlling system need also to consider the "eco-design" strategic requirements on material import.

Another example is from the impacts of "competence level". A corporate auto-definition of "environmental concern" has been defined focusing on the topics of material, such as the dematerialization or the decrease of hazardous substances. In order to answer this definition, a related corporate tendency of competence development might be established, which focuses on the related topics of internal training and the recruitment needs. But the lack of other competences leads to a low level support to other needs coming from some projects, such as the energy efficiency or GHG emission. So the identification of the "eco-design" methods to answer these "non-key" topics for the project should be enough simple and easy to understand by no professional person.

Transverse, as a united organization, the identification of environmental activities and related methods in enterprise needs to consider also the coherence among different corporate functions and all stakeholders. Because the environmental issue is not a simple issue with a "single master", the activities of any related internal functions and external stakeholder could directly or indirectly affect the final environmental performance. ISO 14064 and the classic LCA methods presented also that a classic and precise product life cycle improvement measured and realized into design team might be supported by some contributions from operational departments, such as the production process, the imported materials evaluation and the logistic optimization, etc. For example, the real product's recycling performance is directly designed by the product designer, but the efficiency of "take-back" system and the related selection of recycling methods are also important. Additional, the implementation of "take-back" system requires the collaboration among different functions or stakeholder, such as a clearer and attracter communication manner to final user, an improved reversal logistics network or a force take-back partner, etc. So the working flow, the collaborative channels and manners between these activities and the coherence with their departmental contexts (competence, habitude, location and finance situation etc) are also necessary to be focused on.

So facing these interactions leads to a challenge for integrating the environmental issues in enterprise: **How to organize and optimize the network of environmental activities which contribute to the product-oriented and organization-oriented approaches?**

At theoretical level, [Ammenberga and Sundin[a], 2005] and [De Bakker F.G.A., 2002] stated that beside of energy/material and waste flows in production process, the final product presents also some important environmental impacts. [Ammenberga and Sundin[b], 2005] interviewed some auditors and indicated that the environmental management system should integrate the aspects of product if it presents a significant environmental impact. [De Bakker F.G.A., 2002] indicated that the approach to corporate environmental management has changed over time as, next to cleaning technologies and pollution prevention, forms of product-oriented environmental management have to be developed and integrated. [Jørgensen T.H., 2008] indicated in order to establish a more sustainable management system, that it is necessary to take into account the interrelations between the production process and the final product, to achieve a more holistic view on two areas. For instance, the environmental improvement of a product must be considered in relation to the impacts on quality and health and safety. Additionally, ISO 14001 pointed out the environmental management systems that can be used in connection with product design. The organization could identify the environmental aspects and establish procedures to identify and track development in environmental, legal and other requirements applicable to its product. It could also define, design, initiate and maintain appropriate training programs to ensure employees to adhere establish and develop environmental standards or practices.

[Hallstedt S., 2010] indicated that a systematic conversation channel between two axes could support the enterprise to make a suitable identification of environmental activities and related methods. This systemic model needs to treat the compatibility of all potential environmental activities to ensure the tendency of corporate development. It also requires organizing the cooperation among different activities. [Baumann H., 2002] indicated that there is a lack of systemic perspective to analyze the relationship between strategic intents and eco design practices.

So, a hypothesis is that there is a positive influence to take into account all relationships among eco activities and related methods according to the context of an enterprise. This relational analysis could support the identification of suitable combination of environmental activities. And this harmonization could accelerate the corporate environmental optimization.

Chapter 6 - Needs for a systemic and holistic view for environmental integration

The growing attention given to sustainable development is encouraging companies to integrate sustainable issues into their activities. The integration of environmental consideration, including the product-oriented and organization-oriented approaches, leads to a significant organizational change [Le Pochat S., 2004]. Therefore sustainable strategy cannot be considered as an independent issue. Depending on the organizational structure and the definition and responsibilities of each corporate function, some literatures point out that sustainable aspects should be embedded at all corporate hierarchical levels, from global strategic decisions by top management, throughout planning and organization by tactical management, to daily engineering and production activities of the operational area [IEMS, 2001], [Reyes T., 2007], [Hallstedt S. et al., 2010].

This chapter is to point out that a systemic framework is necessary to optimize sustainable integration. This framework is supported by a flux of information related to environmental concerns in the whole company in order to ensure fulfilling corporate tendency and enhancing the internal collaboration to achieve environmental objectives. The following paragraph 6.1 summarized the actual model of strategic decision and then presents how strategic options and necessary resources are defined based on the environmental knowledge of the company. Secondly, paragraph 6.2 indicates that at operational level, an in-depth analysis of the operational conditions about the identified environmental practices has to be defined. And finally, In order to answer the informational consistency, a framework including a uniform intelligence support and a circulation flux among whole company is presented into paragraph 6.3.

6.1 Intelligent support for strategic decision

Corporate social (or societal) responsibility (CSR) can be defined as a corporate contribution to sustainable development, and the related "overall performance" may evaluate achievement. This stakeholder-centered vision is an alternative to the traditional vision which is only responsible for financial performance to the shareholder. [Charreaux G., 2001] proposed an enlarged definition of value creation embedding the stakeholder value. The stakeholder-centered view of the company allows a reconsideration of value creation and value sharing in the company so that it is not merely oriented towards shareholders. So in this context, more and more corporate strategic decisions have to be taken

6.1.1 Strategy and sustainable strategy

Corporate strategy, in Porter's perspective [Porter M.E., 1979], is the art of positioning the company's activity in the best place on the value chain regarding competitors, and optimizing its added value. This vision of value creation is modeled by a series of value chains. Despite their importance in the value-creation processes, these chains are no longer the primary mode by which overall value is created along the value chain: like technological innovation, customer relations, which are determining factors of the overall value-creation system [Normann R., 1994]. In fact, value creation has been evolving in line with economic models from the early industrial revolution to the latest developments such as the service economy [Buclet N., 2011[a]] or collaborative consumption models [Botsmann R., 2011]. Actually, fundamental resources are no longer the only resource which drives the development of organization and marketing, but the knowledge and relationship with stakeholders should be considered [Normann, 1993]. Economic models evolve and make value creation models evolve with them, from a chain of added value [Porter M.E., 1979] to a complex value network [Allee V., 2000]. In the current knowledge–based economy, one major strategic challenge is how to reconfigure a company business, starting from the value creating system itself. Stakeholders are co-producers of value and company strategy is based on the constant reconfiguration of interactions between actors [Allee V., 2000], [Normann R., 1994]. The value chain has mutated into the value constellation. These days, organizational innovation is a key to success in an uncertain and competitive economy. In this approach, [Normann R., 1993] defines corporate strategy as the art of creating value.

[Johnson, 2008] defined corporate strategy as the combination of strategic analysis, strategic choice and strategic implementation. In a sustainable perspective, integration of stakeholders' needs (and expectations) into corporate strategy is a key point for any corporate sustainable process [ISO 26000, 2010]. Sustainable strategy can be understood as the creation of value to answer stakeholders' expectations and needs, if this does not conflict with sustainability.

[Hallstedt S., 2010] proposed a review of sustainability integration methods, tools and concepts in strategic decision systems. Different approaches are cited, including forecasting, that uses current trends to define a likely future. However, in uncertain and very fluctuating contexts, it is risky to predict the future. The "back casting" approach freezes the future in a desirable state (success) and then creates a pathway to reach this desired future from the present. Nevertheless, it can be hazardous to create a consensus on a desired future, given the divergent expectations of multiple stakeholders. Consequently, the "framework for strategic and sustainable development" (FSSD), developed by [Azar C. et Al, 1996] is an open-ended and non-prescriptive framework that proposes some sustainability principles. Three of these four principles are connected to environment. First and second principles concern substance flows from different origins (lithosphere and society) to ecosphere. The third principle is about the protection of ecosphere production capacity and the protection of biodiversity. The fourth principle is about resource use efficiency regarding human needs. These four principles are mainly oriented to environmental issues. [Buclet, 2011b] proposed further three principles of coordination between actors to modify the current inconsistent paradigm with sustainability. First, the proximity principle between the decision level and the level affected by these decisions, which is divided into physical, organizational and institutional proximity. The capability principle aims at respecting and developing the individual's ability to meet its own goals. And the participative democracy principle enables a balance between liberty and collective constraints and between individual and common interests.

Beside of these above classic process to identify the corporate strategy which is usually named as the "Deliberate strategy[31]", the company needs also to face some unexpected "emergent requirements". According to [Mintzberg H., Waters J.A., 1985], the emergent requirements mean that the company or certain projects are required to treat some sustainable topics which have not yet been planned in-company. These requirements also present particular needs for some neglectable topics from the strategic level.

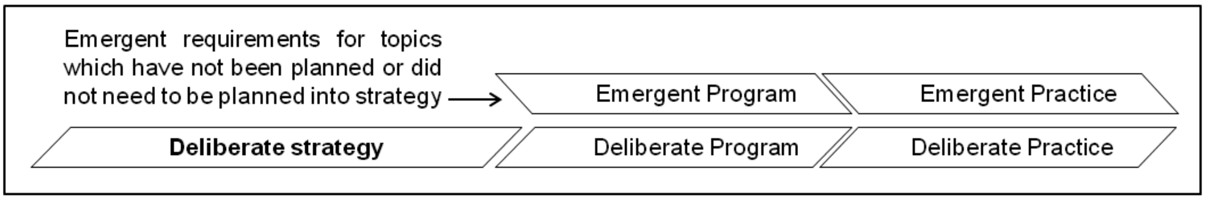


Figure 6-1: Macro-work flow for emergent requirements

For example: specific requirements of dismantling process for the product category, which is outside the legislation area. If necessary, the treatment of these topics may answer

[31] Deliberate strategy is a strategy that is made intentionally by an organization so as to achieve its intended strategy or some concreted final goals [Mintzberg H., Waters J.A., 1985].

requirements. Furthermore, this can update and complete the corporate knowledge and competence level, which may affect future strategic decisions.

6.1.2 The integration of stakeholders into strategic decision

The way in which stakeholders are identified and integrated into the strategic analysis is decisive in defining sustainable strategies.

Freeman defined stakeholders as any group or individual who can affect or be affected by the achievement of the organization objectives [Freeman R.E., 1984]. This broad definition addresses the parameter of who should be considered as stakeholders. [Mitchell R. et al., 1997] proposed a partition and classification of stakeholders based on three criteria: urgency, legitimacy and power. He identifies eight different types of stakeholder ranging from non-stakeholder to definite stakeholder. In fact, traditionally, stakeholders were selected with regard to their proximity to the economic activity of the company. [Hillman A., 2001] underlined that the integration of stakeholders closest to the economic activities could improve economic performance. [Bieker T., 2001] proposed some visions of strategic orientations other than the profit-centered vision. The green case, in economic and social spheres, is dedicated to environmental protection. And the social case, in environmental and economic spheres, develops human rights. These alternative visions require the tools to control new objectives. In this research, the concept of overall performance comes from this new vision of the company.

6.1.3 Corporate overall performance and its measurement

Performance measurement of an industrial system is mainly about cost, quality and time. This measurement system is not relevant to manage the strategy to meet multiple stakeholders' needs. Overall performance is defined by [Baret P., 2006] as the aggregation of economic, social and environmental performance. However [Capron M., 2006] underlines the lack of integration and balance between these three dimensions of sustainability given by the strategy definition. He qualifies this performance as a search for integration and equilibrium between the triple objectives of sustainability (economic, social and environmental). Overall performance evaluation is a multi-domain enlarged management control system that measures the company's economic, social and environmental behavior. These performance evaluations are directed at multiple stakeholders with multiple objectives [Quairel F., 2006].

The Balanced Scorecard (BSC) [Kaplan A., 2001] and its prolongation for CSR (Sustainable Balanced Scorecard [Hockerts K., 2001] and Total Balanced Scorecard [Supizet J., 2002] connect the financial performance and its drivers with a multi-perspective approach. Despite this balanced and multi-dimensional set of measures, these tools are dedicated to financial performance.

The performance prism [Neely A., 2007] proposed a stakeholder-centered view of performance measurement. This approach focused on value creation for stakeholders. The central issue becomes the identification of stakeholders and the understanding of their expectations and needs [Neely A., 2007]. The author emphasized that his proposition does not assume that all stakeholders are equally important. From his point of view, consideration must be given to traditional stakeholders such as employees and suppliers. However it is clear that for most of the company, shareholders remain the most important stakeholders. He also noted that the only reason for an organization to have a strategy is to deliver value to some stakeholders.

To summarize, there is no shortage of different approaches and visions of the company to guide decision-makers through corporate strategy definition. The key point for sustainability is to identify stakeholders' needs and interests and to involve them in the decision-making process and activities. Therefore, performances of sustainable strategies have to be managed by using tools adapted to this approach.

6. 1.4 The determination of strategy requires a holistic intelligence support

[Yen Y.X. and Yen S.Y., 2012], [Johansson G., 2002] and [MacDonald J.P., 2005] demonstrated that a clear strategic planning for sustainability plays a significantly role to pilot the environmental integration and drive the various development roadmap. The corporate strategy about environmental aspects could provide a particular and clear definition about the environmental characteristics of thus company, the related developing tendency, and a strong support for related research and initiatives. In order to determine the strategy, whether the deliberate strategy or emergent strategy, the company must understand fully the internal and external environmental factors that affect it, such as the context in which it operates and the available strategic options, as more as possible. [Johansson G., 2002] summarized this issue by pointing out other major related success factors for integration of eco-design to take into account: an efficient and systemic internal management to relate the environmental goals, methods/tools and develop the required competencies. [De Bakker F.G.A. et al., 2002], [Jorgensen T.H., 2008] and [Erlandsson J. and Tillman A.M., 2009] presented a similar viewpoint. [Zhang F., Zwolinski P., 2011] furthermore indicated that several operational conditions of tactic decision, such as the financial support, the time frame, the technical complexity of program are affected by the strategic decision. Especially the selection of suitable environmental method should consider several strategic preferences: such as the leadership, the reduction of operational cost and time, the competence development, etc. In order to improve the environmental aspects, the harmonization between the environmental strategy and the selected practices should be considered at the planning stage. Inversely, the strategic decision is also necessary to involve an in-depth intelligence of available implementing options in order to make the corporate strategy more creditable and achievable.

By using the SSD framework in 6 companies, [Hallstedt S. et al., 2010] indicated that the third step, "strategic guidelines" is necessary to be supported by a strong decision support system that provides the technical and operational details of the environmental methods, tools and concepts for decision making, as well as data and actors involved at different organizational levels.

The suggestions from IAPC (International Association of congress centers) pointed out the same opinion that the establishment of environmental strategy requires looking at variety of possible areas and the available practices implemented by other organizations. Considering the actual corporate contexts and objectives, the company fills out the right options' group to construct the sustainable mark.

[Zhang F. et al., 2013] and [Wagner M., 2007] pointed out also the success of strategic deployment; especially the suitability of the selected strategic roadmap depends on collaboration between strategic objective and the exploration of intelligence support about all available implemented options. This support is necessary to provide the potential options to meet the needs of strategic objectives and list the details of each option to support the final decision. The completeness of this support ensures the translation of the strategic objective into the right manners of implementable strategic goals.

[IEMS, 2001] indicated also that in order to answer the corporate environmental policy, the setting up of an available action list is the first step. And the quality and the complexity of potential action support are further two key elements which affects the final success of implementation. Meanwhile, [Le Pochat S., 2004] pointed out that the environmental integration is a significant change, and for any type of change, there are always some risk and barriers, like the motivation of all employee, the new dashboard of working performance evaluation, need to be considered at strategic level. [Reyes T., 2007] illustrated that a clear declaration between the environmental objective and the required activities might encourage the initiative of each employee.

But [Waage, 2007] stands out till now that the unclear linkages among tool, methods and environmental strategy is a big reason for the lack of successful environmental conscious product. [Hillary R., 2000] indicated that "lack of knowledge in relation to environmental issues, compounded by a perceived lack of information and support, has widely been identified as a major constraint to identify the right environmental strategy". Furthermore, he demonstrated that the involvement of more environmental knowledge about the practices and the operational conditions might clarify the strategic options and the necessary resources to access them.

6.2 Intelligent support for operational integration of environmental program

Once the environmental program has been defined, it should be integrated into the actual working process. [Le Pochat S., 2004] pointed out that this integration produces a significant organizational change. It's due to the set of actions, methods and tools defined by the environmental program that should be studied and embedded, and also because the necessary competency needs to be created and developed to ensure the operation of such actions. [Reyes T., 2007], [Millet D. et al. 2003] and [Autissier D., Moutot J.M., J-M., 2003] indicated that there are several types of environmental change and whatever the type to be implemented, it's necessary to face the challenge about the involvement of new methods and tools (it was discussed into chapter 4), the creation and development of new green competencies, and the modification of actual corporate habitude and process.

6.2.1 Competency management requires a systemic view of final goals

In order to integrate the environmental aspects into company, several environmental knowledge are necessary to be imported, created and developed. At first, the corporate environmental initiative requires to learn new practices and related knowledge and technologies to prevent the pollution and optimize the environmental performance. Meanwhile, the environmental initiative often leads to the substantial saving in materials and energy. This process calls for the involvement of all employees held on the new "know-how" as well as learn the combined working methods [Boiral O., 2002].

From [Snowden D., 2002], there are two different types of knowledge: the "tacit knowledge" and the "explicit" knowledge. The "tacit knowledge" illustrates some internalized skills or competencies that the employee are not consciously aware of it; and inversely, the "explicit knowledge" represents the knowledge hold by an individual in a codified or identifiable form that could easily communicated and diffused to other individuals. Several researches pointed out that a successful framework of knowledge management is to convert the implicit knowledge into the explicit form in order to share and monitor the development of them. This framework is necessary also to permit the individuals to internalize and make personally meaningful any codified knowledge retrieved from the knowledge management.

[Reyes T., 2007] summarized the framework proposed by [Nonaka et al., 1996], the knowledge is created through the interactions of different types of knowledge (tacit and explicit) and the contents of individual ideas. Particularly, they recognize the contextual and relational aspects of multidisciplinary requirements which lead to some difficulties to share the knowledge. They offered a representation for transforming "individual knowledge" into "collective knowledge" by four modes of conversion: Socialization, Externalization, Combination and Internalization. Following this framework, the implicit knowledge is 'extracted' to become explicit knowledge, and explicit knowledge is "re-internalized" into implicit knowledge.

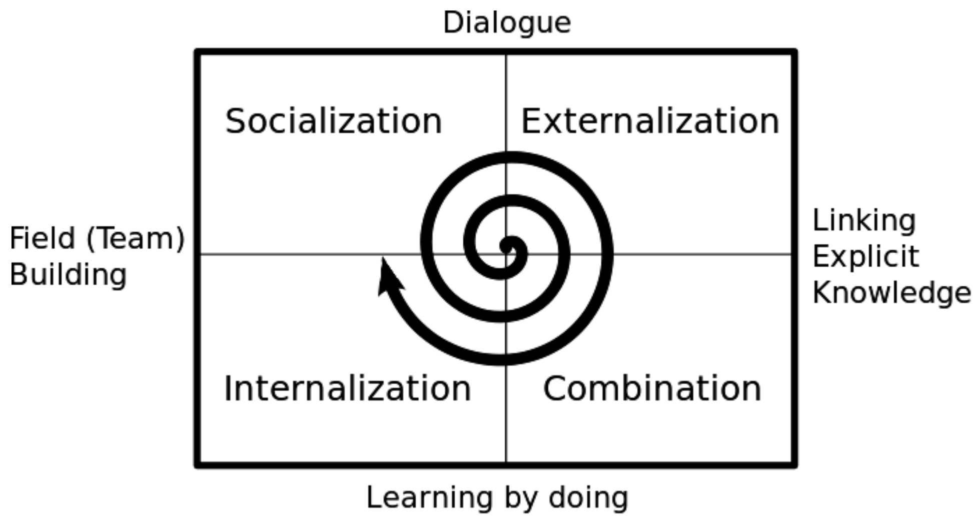


Figure 6-2: Knowledge spiral proposed by [Nonaka et al., 1996]

The "Socialization" is a process of creating tacit knowledge (technical and cognitive) through an exchange of experiences and information sharing within the multidisciplinary context and formulated objectives. Then, the "externalization" is a process to collect the created tacit knowledge and convert them into the explicit form which ensures the ability to share among multidisciplinary. Facing to new explicit knowledge, the “combination” is a process to integrate the new arrives into the existing knowledge framework. The multidisciplinary groups work together to further develop this new knowledge. And finally, the “internalization” is process to re-transfer the formulated explicit knowledge into the individual tacit knowledge by the knowledge receptors which operates them in practices to exactly acquit the knowledge.

Accompanying with the above knowledge translation process, a critical problem needs to be answered: How to manage the creation and the development of knowledge in order to accelerate the integration of environmental aspects. According to the term definition of Australia standard - AS5037:2005, the competency management, usually named as “knowledge management (KM)” is defined as a corporate global framework comprises a range of strategies and practices aims at identifying, creating, distributing and enhancing collective company’s skills and competencies[32]. The competency management is to bridge the skill gaps (between the required goal and the actual level), especially facing to the topics and domains that employees have never practiced.

[Boiral O., 2002] summarized that the process of environmental knowledge management into three steps: the consultation of employees, the codifying of implicit knowledge, and “custom-made” training.

The “consultation of employees” is to externalize a dashboard of actual tacit competencies and skills of each individual by meeting directly the employee, in this step, [Grundstein M, 2006] indicated that it’s necessary to clarify two types of knowledge, the explicit knowledge and the tacit knowledge about know-how. After the collection, the “codification” process is to make the tacit knowledge explicit. But this codification does not mean for all existing knowledge. The auto-motivated knowledge of each individual could enlarge the portfolios of eco-innovation, but the definition of the knowledge which has the first priority to be developed, is necessary to consider the corporate potential needs [Zhang F., 2012]. [Boiral O., 2002] pointed out the invaluable information and related knowledge affect the efficiency of the environmental integration. ISO 14001 requires the company setting up the knowledge management according to the needs of corporate environmental policy, which includes the strategic operational plans, objectives, responsibilities, performance measurement and the audit forms. The third step is to make a “custom-made” training to fill the gap between the required knowledge and actual. The external intelligence could be involved to initialize the

[32] The definition refers to the term definition of AS (Australia standard) 5037:2005, knowledge management

environmental program. [Snowden, D., 2002] defined it as the "Personalization approach" which represents that the individual expert can directly provide their insights to the particular person or people needing this. And this importance of intelligence could enhance the knowledge's level and immediately import the necessaries. [Autissier D., Moutot J.M., 2003] indicated that knowledge management of environmental issue should identify the details of three axes: the internal communication and promotion of necessaries, the training design and the accompanying after the training in order to evaluate the performance and make a close-loop knowledge revision. Similarly, [Perrin F., 2005] analyzed the literatures and pointed out the necessity to create a centralized expertise team to uniformly provide promotion, the training and the accompanying. Further, the details of the new tools and the new methodologies, especially, the interactions among different tools are required to be highlighted. [Reyes T., 2007] summarized that the related competency training needs to follow a global logic, which could explain why the company needs to change, the realization process, the contribution of each function and its responsibilities and finally, the means and format of knowledge's transformation. This global view about the program to be implemented is better than just focusing on the training of new tools.

6.2.2 Process design for compatibility requires a systemic view

Several literatures indicated that the environmental actions are not the independent issues, which are necessary to be embedded into the normal process of a company, or further involve into the "DNA" of a company. The product design and the corporate activities should make the balance of several conditions, such as the financial condition, the quality requirements, the deliverability, etc. So in order to integrate the environmental aspects into the existing framework of decision-making and optimize the efficiency of integration, a systemic design of related interface and the informational flow between the environmental action and normal action are necessary to be developed [Knight P., and Jenkins J.O., 2009].

From the managerial point of view summarized by [IEMS, 2001], the operational management needs to pay attention on four issues: the operational controls (which means the summary of operational procedure and the indicator system to measure the performance of each step); the planning of implementation; the organizational support (which include the inter- or extern-communication, training, seminar and meeting and the stakeholder involvement) and the monitoring and documentation of working flow.

From [Robèrt K.H. et al., 2002], they summarized that at operational level it's required to focus on two main issues: the planning of the "Action" network which organizes the implementable plan for each strategic decision; and the second issue is the "Tools" which selects suitable environmental tools, and create the interface to involve them in daily activities of company.

[Bassetti A.L., 2002] indicated that the integration of sustainable issues requires a structural change of company. This change should consider the "individual change" and the "organizational change".

Individual change focuses on the detail working flow of each individual employee, such as its knowledge development, the contents and the format of informational exchange, the detailed exchange model and channel with new green functions.

The "organizational change" is established in the global improvement at corporate process level, including the systemic exchange system and the development of new corporate culture or habitude.

[Knight P., and Jenkins J.O., 2009] further pointed out that it's necessary to take a deeper configuration to make the "compatibility" between the all contents proposed by methods and the real corporate context, including the actual working process, collaborative habitude and the competency structure. By the examples of the application of the checklist, guidelines and Matrix life cycle analysis by MET Matrix, they explains that, the contents, the work timing, the interface for data exchange should be modified and re-defined to adapt the theoretical methods to the real competence and process environment.

By a survey about existing industrial practices from [Tukker et al. 2000], a small number of companies have some practical experiences to involve the environmental aspects. One of principal barriers is the systemic and efficient informational exchange among different stakeholders. In Tukker's report, this exchange might appear both inside of company or inter-companies. Finally, he suggested an analysis about the exchange model and training of the company about this topic.

By a survey of 376 American companies, [Song X.M.et al., 1996] indicated the similar opinion that the multifunctional coordination depends on the accurate and efficient communication and the informational exchanges among different functions. Meanwhile [Wagner M., 2007] presented also that the collaborative communication and platform among different corporate functions is a principal risk of environmental operational integration. And [Song X.M. et al., 1996] summarized five barriers:

- The lack of trust or respect of informational exchange. And Personnel perceive a lack of credibility in team members from other units[33].
- The physical proximity leads to the difficulty of face to face communication.
- The different orientations contribute to a lack of communication and integration. Different ideologies, languages, and even goal orientations lead to miscommunication and a general lack of communication and integration.
- The lack of formalized communication structures in particular, and a lack of communication in general, as barriers to effective cross-functional integration. Meanwhile, [Tukker et al. 2000], pointed out also it's difficult to plan the movement from face to face communication into a collective communication which needs a systemic view of all necessaries in order to promote greater acceptance of operational and therefore facilitating a result.
- The lack of managerial support for integration was a barrier to informational exchange and integration. The conflict between the managers and design project and the lack of enough time for planning requires a holistic dashboard of all necessities.

Some authors considered the environmental issues as a new manner for innovation. From the point of view of innovation optimization, [Mercier-Laurent, 2003] indicated that there are 4 topics which need to be considered: a sharable version for all related actors; a management commitment from the top managers about the perspectives; a systemic approach of implementation; collaboration with clients and competitors. Finally, these topics all require a systemic and holistic view of the implementing actions and their detailed operational conditions.

6.3 Necessity to improve the decisional circulation among whole enterprise

Today, the company is facing needs for vast information exchanges among multidisciplinary background. [ISO 14001, 2004], [EMAS, 2009] and some product-oriented environmental management systems require a strong internal and external communication to avoid the

[33]Example from [Song M. et al., 1996]: that marketing personnel do not trust the information received from R&D, and vice versa.

misunderstanding and ensure the exchange efficiency among the whole company. This strong communication might optimize the measure of the environmental impacts, definition of action plan, as well as the monitoring of the improving process. By analyzing the industrial practices, [Wagner M., 2007], [Jørgensen T.H., 2008] and [Ziegler A., 2009] demonstrated that the implementation of environmental management system with a better collaborative aspects presents a positive effect exclusively on environmental process innovation.

[Hallstedt S., 2010] stated out that a systemic framework with a uniform and optimized circulation of decision and data flows connecting various levels and functions is necessary to optimize sustainable integration. She indicated that actually, in particular for SME, sustainable issues seem to be less understand, and are not yet systematically covered by some supports. In Hallstedt's model, the decisional flow of environmental integration circulates among three different levels: the senior management level (Identification of strategic orientation), the product development level and the production level. For each level, the words like "sustainability" and "environment" should be broken down into concrete actions or attributes that can be understood, quantified and addressed, is necessary to be evaluated and prioritized among alternative solutions, and follow up on their effects. Finally, the decision and the interactions between them is necessary to be supported by a uniform support system "A common language" which could ensure the consistency of decision means of three levels and it might provide a comprehensible exchange and communication inside of the company.

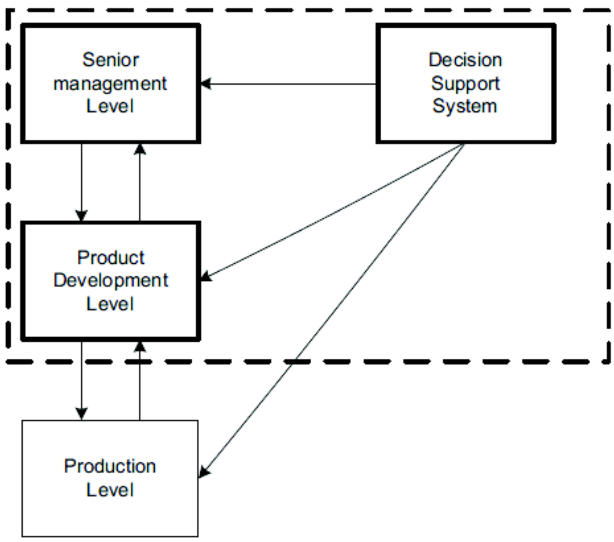


Figure 6-3: Uniform decision support system for corporate entity [Hallstedt S., 2010]

[IEMS, 2001] The method focuses on a detailed uniform informational work flow throughout the entire company in order to realize strategic objectives and collect feedback to ensure continuous improvement. From the previous paragraph, the strategic decision of IEMS system depends on the complexity of potential applicable implementing measures of each environmental topic and the creditable evaluation method to identify the priority of them. According to the evaluative results, the IEMS proposed to create the related operational control system to determine the environmental objectives desired, set targets for performance and ensure these objectives will be met. Finally, the monitoring systems, about the compliance tracking, the status registration, the documentation of working flow, need to be also set up. The contents of these monitoring systems depend on the required criteria of selected environmental objectives.

6.4 Conclusion of this chapter

According to the above states of the art regarding environmental integration into the entire company, this integration needs a systemic approach to optimize the decisional and informational circulation among the whole company. However, there are several major issues between the ideal integration model and current company results. At strategic level, the company needs a legible and quantitative method to evaluate its global situation, including material resources and immaterial capitals and requires an intelligence support to explore maximum potential actions. The complexity and the detailed information support is a key issue to influence the final strategic decision. At operational level, dynamic and flexible information exchanges between corporate daily work and environmental tools are needed to effectively deploy the environmental process as regards the available resources and actual exchange model which require also a systemic view of all environmental necessities.

The last issue concerns the whole systemic approach. The above state of art demonstrated that a better circulation among different hierarchical levels (strategic level, tactic level and operational level) and different function presents a positive effect on the integration of "sustainability". Facing ideal model of “sustainability” integration, it is necessary to support a global collaboration as well as local information flow circulations among whole company. This would contribute to ensure the efficient decisional information flows transfer through the whole company.

Chapter 7 - Synthesis of problematic

The state of the art presented in this part II allows us firstly to highlight several problems related to the integration of the environmental activities into companies. The environmental integration is not an independent issue, it's necessary to be integrated into the whole company. And inversely, the implementation of environmental program needs the support of various corporate functions. The state of the art indicates that the identification of environmental roadmap should focus on three major considerations:

7.1 First point: consideration about strategic decisions

Firstly, the environmental program and all proposed activities are to answer the corporate strategic requirements. As mentioned in the first part of this thesis, the industrial environmental strategic requirements are diverse. The state of the art indicated that there are different types of environmental strategies. Some of them are focusing on the cost of the achievement but some others are paying attention to the final influence and the social responsibilities. Event for a same environmental objective, the different strategic preference requires different operational programs. So the diversity of strategic decisions leads to a problematic: **during the program planning, how to integrate the different strategic preferences into the environmental program?** More precisely, this problematic could be considered as "facing a same environmental objective, could we provide different implementations to answer different strategic preferences? And could we provide a mechanism to guide the selection?"

This problematic requires establishing a depth intelligence support to explore maximum potential actions in order to answer the strategic requirements. The complexity and the detailed information support is a key issue to influence the final decision.

7.2 Second point: consideration about operational contexts

Meanwhile, the decision of environmental program needs to also consider the aspect about "implementability". Several authors demonstrated that a major problem of the environmental integration is that the developed methods are disconnected from the real dynamic of corporate context. The corporate context includes two principal parts: the operational constraints and the actual corporate culture. The first operational constraints which present the limits of the available resources to implement a set of environmental actions, such as the operational cost, the time frame and the knowledge level etc.; and secondly, the actual corporate cultures are represented by the corporate organization, the responsibilities of each corporate function and the working flow among whole company. Today, facing a various number of environmental tools which requires different operational resources, company requires a systemic view for matching the operational necessities with actual corporate situation. And the results of matching are necessary to directly affect the decision about the suitable environmental program. Meanwhile, dynamic and flexible information exchanges between corporate daily works and environmental tools are needed to be designed effectively regarding the available resources and actual exchange model.

So in order to evaluate and prioritize the "complexity" of all potential environmental solutions and establish a systemic planning of roadmap, **it's necessary to set up a mechanism to involve the consideration about the operational contexts into the environmental decision and planning.**

7.3 Third point: Consideration about the relationships between different methods

The two above sections (7.1 and 7.2) summarized that the dynamic corporate environmental targets and operational contexts are necessary to be considered to make the final decision related to environmental integration. But all environmental methods are not independent. So beside of these two points, in order to answer the optimization about the "multi-objectives" and "multi-steps", the state of art indicated that there is a lack of evaluative method that could provide a systemic view on the relationship among the different environmental method (series and parallel) and provide a robust mechanism to make a holistic and systemic decision. This "holistic and systemic decision" means that this available program can handle and treat the relationships among multiple targets simultaneously in the transverse direction (“participatory”, “co-operability” and “trade-off” risks), and in longitudinal direction (focus on the coherence of implementing steps for resolving the final objective).

Meanwhile, the environmental management of a site and the product’s eco design are not two independent issues. The previous chapters demonstrated that there are several positive interactions between the methods of these two approaches. In fact, they are mutually constrained, and sometimes, they are mutually supported. So the identification of the environmental activities to answer one axe’s needs, should consider the constraints from another one.

Facing a vast number of environmental methods in two different approaches, **it’s necessary to establish a systemic model to identify the detailed relationship among different environmental methods.** This systemic model needs to treat the compatibility of all potential environmental activities to optimize the informational network among them.

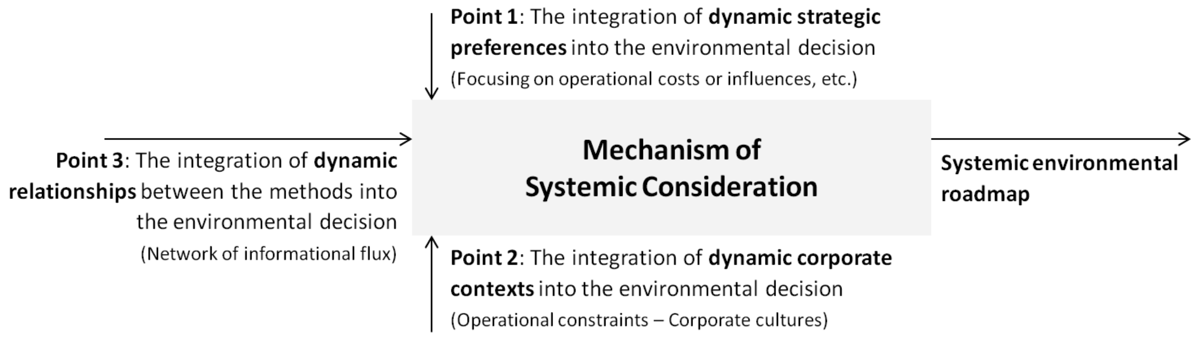


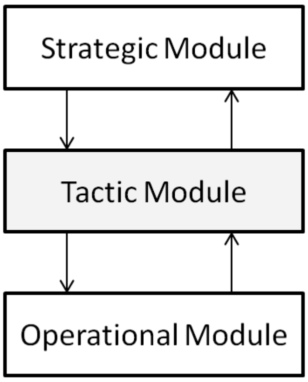
Figure 7-1: The summary of the problematic to provide a systemic model for environmental integration

So, a final hypothesis of this thesis is that a systemic model is necessary to organize the overall integration of environmental actions. This model needs to: 1) make the coherence between selected eco-methods and manage the flow of information exchanged; 2) make the coherence between environmental decision and the corporate objectives and contexts; and 3) make the coherence between corporate tendency and the project’s requirements (the global approach of site-oriented environmental management and product-oriented improvement). Meanwhile, this systemic model needs to be integrated into a better decisional circulation among whole company to presents a positive effect on the "sustainability" integration.

III

CONTRIBUTION TO A SYSTEMIC APPROACH FOR OPTIMIZING THE INTEGRATION OF ENVIRONMENTAL CONSIDERATIONS IN A COMPANY

In order to integrate environmental issues into a company, it's necessary to define a systemic approach which regulates and optimizes the decisional circulation among all corporate stakeholders of the whole company, from global corporate development to product realization level. This research is currently conducted into a national research project called "Convergence" to propose a global solution. According to the responsibilities of each corporate function and to the existing models, "Convergence" built a structural "vertebral column" model with three complementary modules: strategic, tactic and operational modules. The research described in this document is more specifically related to the "Tactic module" which is required to identify a systemic implementable working plan by considering the "strategic" decisions and the "operational" conditions. For this an in-depth analysis of the operational characteristics and of the interactions for each environmental method is necessary to provide a unique intelligence support to make decisions at all levels of the company.



In this part we will briefly describe the "vertebral column" and then the framework of each module and the interactions between them will be illustrated to show how they are necessary to establish the global coherence in the whole company. Then, three applicable scenarios, "top-down", "bottom-up" and "middle-two sides" scenarios will be presented to explain how the working flows of the navigation system resolve the coherence among the whole company.

Chapter 8 - A vertebral column to make coherent the environmental decisions in the whole company

The above problematic indicated that an optimized circulation of information and knowledge among the whole company could improve the integration of environmental issues. However, there are several major gaps between the ideal integration model and the current company scale. At strategic level, the company needs a legible and quantitative method to evaluate its global situation and development tendency. A global approach involving multi-stakeholders is necessary to create the relationship between value creation and sustainable activities in-company. At tactical level, a global and overall approach is necessary to identify a sustainable working plan (with the detailed definition of the working process and related responsibilities), in accordance with strategic objectives and the complex corporate context. At operational level, the collaboration between multi-domain activities (the relationship between the environmental requirements and other functions) should be improved by a dynamic and flexible informational exchanging. A systemic approach is thus needed to ensure collaboration between all levels and to allow an efficient transfer of decisional information flow in-company [Hallstedt S. et al, 2010], [Jorgensen T.H., 2008], [De Bakker F.G.A. et al., 2002] and [Erlandsson J., 2009].

In order to contribute to resolve this problem, a French national research project, "Convergence", was launched. This project, founded by the French National Research Agency (ANR), is associated with four French universities (UTT-Technology University of Troyes, UJF-University of Joseph Fourier of Grenoble, ENSAM and IAE Lyon – Institute of Enterprise administration of Lyon) and two industrial partners: the French Textile and Apparel Institute (IFTH) and Quiksilver©. The final objective of this project is to determine whether sustainable integration could be improved by better cooperative circulation among different company levels, and to propose a navigation-based approach to support this improvement. This navigation-based approach does not only focus on the informational exchange model at the interface of different corporate levels, it also analyzes and provides the practical methods to support the environmental decisions at each level.

This doctoral research is directly embedded into this "Convergence" project and we contribute to the structural design of whole project and specifically, to the development of the "Tactic module". The objective of this tactic module is to identify a detailed and systemic environmental working flow in order to answer the requirements of corporate strategic plan. The interfaces which are related to other two modules, the "strategic" and "operational module," are modulated to ensure the decisional flux circulation. The detailed description will be presented into the following paragraphs.

8.1 Systemic approach to optimize the decision circulation among the whole company, proposed by "Convergence" project

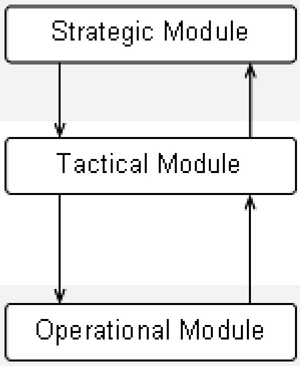
In order to optimize the environmental decision circulation among the whole company, it's necessary to define the responsibilities of corporate functions and the interface between them. The project "Convergence" proposes three modules to illustrate the real decisional responsibilities: the strategic module, tactic module and operational module. And then, three applicable scenarios have been proposed to describe how work the decisional flow transfers among these three modules.

8.1.1 A "vertebral column" model for describing the decisional structure

Firstly, the project "convergence" has to construct the hierarchical structure of company to define the responsibilities of each corporate level. Referring to the proposition of [Hallstedt S., 2010][34] and the classic marketing strategic pyramid proposed by [Berry T., 2010][35], the Convergence proposal is built on three complementary modules: strategic, tactical and operational (*cf.* figure 8-1). This proposal supports the company in adopting a transversal and holistic approach toward sustainability.

[34]Hallstedt defined the hierarchical structure by three levels: senior manager level, product development level and production level.

[35]Berry described the classic marketing strategic pyramid by three levels: the strategic level, the tactic levels and the program levels. Strategy, at the top of the pyramid, is a matter of focusing on the corporate strategic position and the global tendency of corporate development. Tactics set the marketing message and identify the necessary solution that should be transmitted. Programs, at the base of the pyramid, provide the specifics of implementation. Programs include specific milestone dates, expense budgets, and projected sales results.



Supports top manager to

- Evaluate company characteristics
- Harmonize organizational capabilities and strategy

Supports managers and experts to

- Plan program, based on corporate strategy and dynamic contexts
- Set up implementing roadmap to guide environmental actions

Supports collaborators to

- Analyze critical interactions within the corporate function during the R&D process
- Develop models of data transformation between activities

Figure 8-1: A vertebral column of the decisional circulation among the whole company

In this approach, the strategic level assists "top managers" who define the corporate strategic goals that will create multi-values for all stakeholders. In order to respond to strategic goals, the tactical level (represents the department manager or central environmental department) analyzes and organizes the corporate material and immaterial resources (for example: cost, knowledge, Human resource, Relationship with stakeholders or organization.) and develops an implementable roadmap. This matches the strategic goals with specific technological solutions and identifies related "activity chains" to help meet these goals. Finally, the operational level (represents the collaborators of product development or production) supports the deployment of the process in the company in accordance with the tactics (and tools) chosen.

In each module, a list of actions is constituted to resolve the previous problematic issues. The interface and some related interactions are set up to ensure circulation and collaboration between the different modules.

In order to provide a global view about the detailed exchange between the "tactic" modules and the other two modules, some general descriptions about "strategic" and "operational" modules will be described in the following paragraphs. But it's necessary to mention that the details about the propositions of these two modules are out of the scope of this research.

8.1.2 "Strategic" module

The strategic module of "Convergence" project is to propose a decisional support for company which identifies the environmental objectives in the best place on the value chain regarding the competition and the optimization of add values. Beside of the classic financial indicators to evaluate the corporate value, a series of immaterial indicators have been proposed, such as the indicator about the relationship with suppliers, the capacities of innovation or some sustainable aspects.

The “Strategic module” is composed of four sub-modules: the “strategic analysis”, the “strategic choice”, the “strategy deployment” and transversal module to manage performance.

The “strategic analysis” module proposes assisting the decision-makers to collect large amounts of information to identify the current corporate resources and organizational capabilities. With a widened range of information that completes the classical economical financial analysis, this module characterizes the company’s maturity along two axes: actual activities of sustainable aspects and the general situation of and the corporate governance.

The “strategic choice” module accompanies top management in identifying and ranking the sustainable strategies according to different criteria: sustainability of the choice, significance of the stakeholders, and company capabilities etc. Meanwhile, some innovative strategies will also be proposed based on several maturity levels of the company, which are determined in the analysis module.

The “strategic deployment” module allows the identification of the concrete strategic environmental objectives to answer the corporate strategy. The formalization of the strategic roadmap and resource allocation to fulfill strategic environmental objectives are necessary to be prepared. And finally, the “transversal management” module consists in two performance measurement systems with different time horizons and destinations. . The first measurement system is dedicated to measure the performance along the deployment of strategy into the company. A set of the indicators, such as the indicator for strategic achievement (KSI), the indicator for tactics planning (KTI) and the operational indicator to ensure the processing status of implemented programs (KOI) will be established and synthesized. Meanwhile, the second measurement system focuses on the movement of the corporate values, which include the economic values and some immaterial values. This provides a multi-view picture of the overall performance of the firm

8.1.3 “Tactical” module

The tactical module supports department managers and experts in formulating an achievable roadmap to respond to strategic and project needs. As a central module of this systemic approach, the “Tactic” module is required to identify an implementable working plan by considering the coherence with strategic decision form top “strategic” module and the operational conditions from the “operational” module. The principal work of this module is to generate several potential environmental solutions and select a suitable one to answer the environmental objectives. Meanwhile, a detailed roadmap should be proposed which regroups a chain of environmental actions and tools, to pilot the generation of environmental improvements.

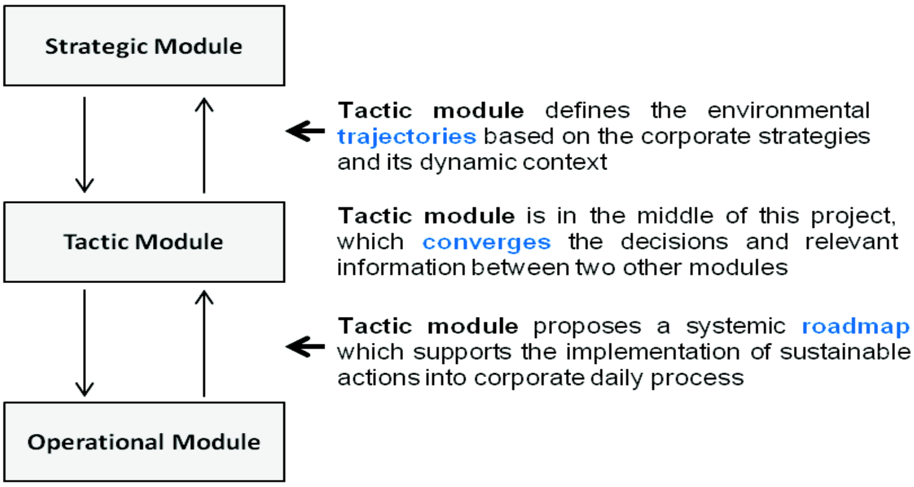


Figure 8-2: The general purposes of "Tactic module"

- **Definition of environmental trajectories based on corporate strategies and its dynamic context**

  The stat of the art indicated that there are a vast number of environmental methods and there are not independent. The interactions among them allow the generation of several potential solutions to answer an objective. In order to select a suitable trajectory to answer the objective, the research works are defined as two parts: the generation of a holistic scenarios map which registers the potential solutions as much as possible; and identification of a mechanism of selection to decide a suitable solution. This mechanism need to integrate the corporate strategies and its dynamic context.

  In order to generate a holistic scenarios map, a depth analysis about the existing environmental methods is required. Finally, more than 300 methods, tools and industrial practices have been evaluated. These methods contribute to the 46 environmental approaches (20 of them for process environmental management, such as the green supplier evaluation, process-oriented LCA, etc. and 26 approaches for product's improvement, such as the design for recyclability, product's LCA, etc.). For each method, this analysis doesn't only focuses on the general characteristics, such as the final purposes of the method, the working process and the necessary operational necessities (such as the resources and knowledge to implement them); but it also analyzes the interactions with other methods.

All results are registered into an environmental cartography which is considered as a holistic database to generate the scenarios map of each objective.

Facing to a mass number of potential solution, the tactic module identifies a mechanism to prioritize them by considering the strategic preferences and the operational implementability.

The "strategic preferences" identify the corporate criteria of the selection. The simplest solution is not always the best choice. The company might also focus on the final influence of the environmental achievement, the duration for implementing, the required actions and the differences with the competitors, etc. Furthermore, the description of the corporate "strategic preferences" is not the same for different company. So in order to avoid the misunderstanding and to simplify the working process, the tactic module identifies a translating system that makes uniform the strategic preferences as a set of measurable indicators.

As the description mentioned into the "problematic part", the complexity of each potential solution is dynamic depending on different corporate context. According to the interactions between the environmental methods, some released actions into company might also contribute the new solution to be implemented. If the company has released the "design for disassembly" to respect the WEEE directive, for example, all released environmental actions could be reused to contribute the new objective about "improvement of product's recyclability" or the "integration of the remanufacturing process". So this type of contribution could dynamically reduce the complexity of certain solution. But inversely, some corporate context might also augment the complexity. The typical example is the lack of required knowledge and environmental data and the company needs to create the preparatory step to develop them. This additional time and related cost augment the complexity of certain solution's implementation.

So in order to prioritize the potential solutions by "strategic preferences", "Tactic module" defined a "Gap Analysis" to integrate all dynamics. According to the outputs of "strategic analysis" sub-module, there is a summary of corporate situation about the material capitals (operational budgets, human resources, etc.) and immaterial capitals (knowledge, organization, culture etc.). In other side, the explored environmental solutions provide a list of operational necessities for each potential solution. Basing on these capitals and the necessities, a "Gap" analysis will be launched to evaluate if all required operational resources is prepared in company. And the summary about the inadequate resources dynamically modifies the complexity of each solution.

Depending on these "strategic preferences" and the results of dynamic evaluation, "tactic module" supports the company to identify a suitable solution to release the environmental objectives.

- **Propose a roadmap which supports the implementation of sustainable development's actions into corporate daily process**

  Once the suitable solution has been selected, it's necessary to define an "operational programming" procedures which defines the objective achieving process, step by step, with the responsibilities of each related corporate function. This working flow is necessary to relate with real corporate daily process and the required action should be embedded into the right step. In order to release these works, a depth analysis or survey should done to summary the actual process and identify the manner of integration. Meanwhile, achieving success in implementing environmental actions for each objective depends upon making sure that each relevant worker has received adequate training. So develop a training program and internal promotion plan that ensure everyone understands both the objective and their role in ensuring that they are followed.

  Once these contents have been clarified and defined, these details will be transferred to "operational module" to optimize the interaction manner basing of federation of engineering tools.

8.1.4 "Operational" module

The operational module provides a flexible and dynamic framework based on federation of tools, which supports the design process deployment in line with the defined tactic program. The aim is to optimize the interactions needed between the product design process and environmental engineering activities (supported by tools, software).

Depending on the defined action plan, this module analyses the data interaction between environmental and product design activities and helps to perform these activities in line with the existing working environment. Activities sequencing is optimized by an efficient interoperability between the product designer's tools and the selected environmental tools. Some "mappings" are defined and implemented to federate tools. The mappings are obtained by formalizing the links between the data input needed to perform the given activities and the data output created in each activity. The design process is therefore defined and deployed progressively. This operational process is flexible to changes and allowing dynamic data exchanges between the activities involved. The proposal verifies the following properties:

- Adaptability to different contexts of tools defined by the tactic;
- Use of any available data needed during the deployment of the design process;
- Linking the global environmental parameters to local product design domain parameters

The integration of environmental parameters (as well as socio-economical parameters) into the designer's activities can be facilitated by this proposal [Rio M., 2013]. One of the difficulties encountered in the operational module is indeed to give capacity to local designers to take into account the environmental parameter when performing their activity. Integration will be effective when:

- Designers understand the link between the parameter they are mastering and the environmental parameter that is dependent on its variation;
- A support provides the direct link between the parameter they are mastering and the environmental parameter that is dependent on its variation. This support may be based on a federative solutions (information systems level) coupled to a specific plug-in in product designer's software. In some cases, there is no need to develop a plug-in. For example, some local environmental tools can be used as an "environmental analysis results" viewer: the sustainability module in CAD software for instance. This support enables designers to reiterate their choice effectively.

8.2 The interface between the three modules to improve general coherence

To improve the integration of environmental issues and avoid misunderstanding, a systemic approach is necessary. As the middle module of this systemic approach, In order to ensure the common language of internal communication, the "Tactic" module, playing an important role should have the capacity to ensure collaboration with other two modules and to provide an efficient transfer of decisional information flow in the entire company.

To respond to this issue, this "tactic" module identifies some information flows among the three modules, known as "interfaces".

- The interface between strategic and tactical modules

The principal transfer between the strategic module and the tactical module aims to receive the strategic decision and report the related performance indicators. Once the strategic module has broken down the global tendency into compositional strategic targets, these targets and all related analyses and supports (such as data, situation analysis, initial position and movement of capital) will be inputted into the tactical module to guide the identification of the implementing plan. Furthermore, key strategic performance indicators (KSI) are established and translated to observe and guide the implementation.

Depending on the received strategic targets and constraints, the tactical module defines the roadmap to ensure the final achievement. This definition should be transferred to the strategic module to ask for a final validation. As a complement, in line with each KSI, a series of key tactical performance indicators (KTI) are ideally defined to measure the processing achievement of KSI. Finally, during the implementation, the KTI score is continuously reported to the strategic module to modify the KSI score.

To establish the initial company evaluation and follow the continuous updates, the tactical module provides the related data, in particular professional data on sustainable development, to the “strategic” module. The tactical module may also be involved in the decision process to provide propositions (for example, the tactical module can show if there are methods available to resolve a given issues).

- The interface between tactical and operational modules

The “tactic” module transfers the defined roadmap and all related operational documents to the “operational” module. This roadmap includes the selected environmental methods and tools, the timing requirement of launches, needs of inputs and types of outputs. This roadmap also defines the roles, responsibilities and actions of stakeholders involved at each step. Depending on this roadmap, the “operational” module may perform the real activities and processes to implement the program. Finally, in order to improve each KTI level, a list of related key operational performance indicators (KOI) is created. The report of KOI results provides real feedback to modify and update the tactical roadmap.

Conversely, to ensure the dynamic generation of design ideas, which includes some autonomy activities that are not yet included in the roadmap, the “operational” module has the capacity to transfer the newly generated methods and solutions to the “tactic” module. This transfer updates and completes the corporate method database. Then, if this new idea has visible effects on the operational condition, the transfer may generate some modifications in the roadmaps.

8.3 Applicable scenarios of this systemic approach

In line with the previous presentation of the three modules and interactions, three applicable scenarios are proposed to transfer the decisional flow, indicators and competences in order to support a systemic integration of environmental issues into whole company. In following paragraphs, the “Top down” presents the first applicable scenario, which defines how to plan some implementable activities, in order to respond to strategic requirements. Conversely “bottom-up” presents how the actual operational environment (process, technical possibilities) affects strategic decision-making. Finally, “middle-two sides” presents how to integrate some additional sustainable issues in the company. This scenario may appear in some emergent situations, when answering to specific requirements, for instance.

8.3.1 “Top-down” scenario

The “top-down” scenario illustrates the proposed knowledge and decisional ordering process for integrating all selected eco-design activities into the company, from global strategy (strategic level) to practical collaboration (operational process).

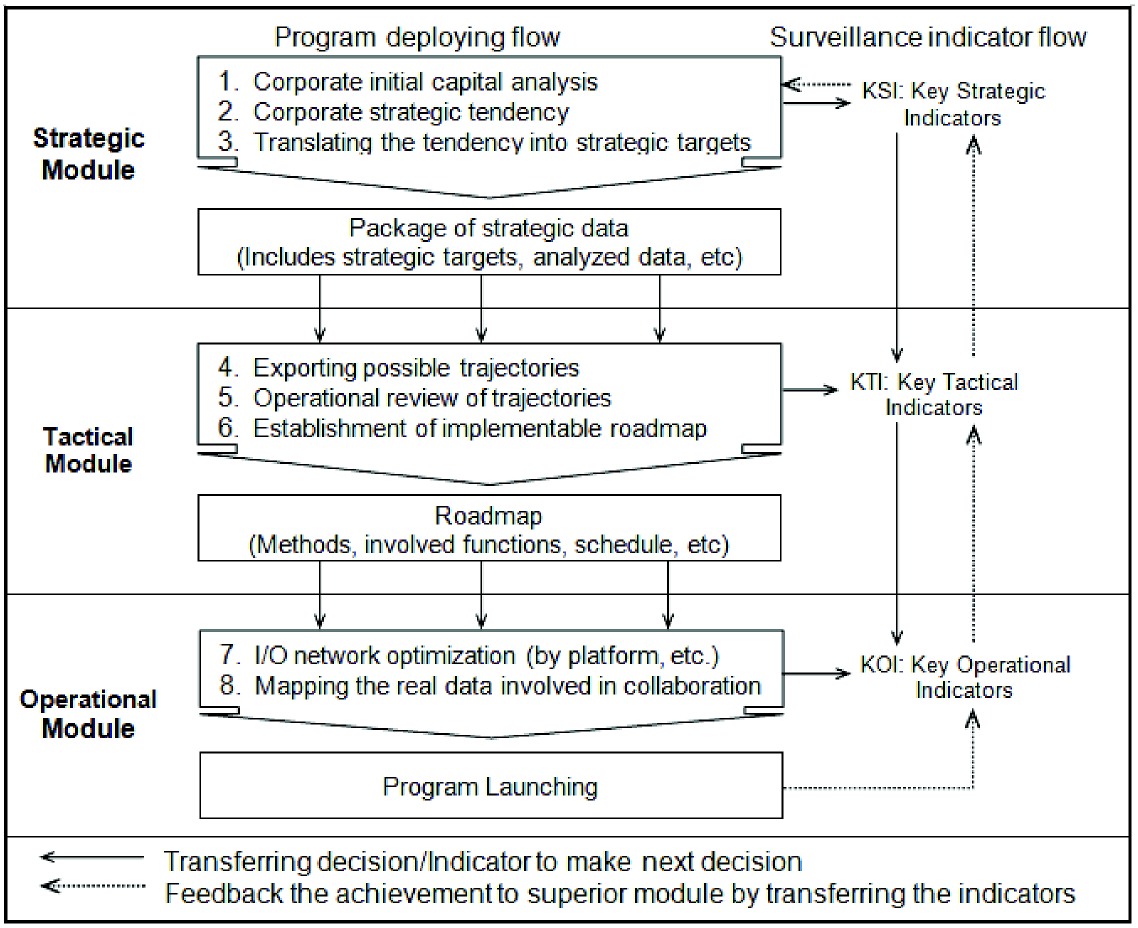


Figure 8-3: Working flows and decisional transfers for the “Top-Down” Scenario

At first, the strategic module proposes an overview and a scoring system to present the corporate context, requirements, and corporate needs. Depending on the above quantified results, the strategic module establishes a global sustainable tendency, which will be broken down by some compositional strategic targets. Then the strategic description of targets and additional analyzed data are translated to the tactical module. According to this strategy, the tactical module explores all possible trajectories in the sustainable methods database. By the iterative simulation of the feasibility and the capacity to implement of the trajectories, a corporate acting roadmap to conform the operational constraints and needs above targets is planned and formulated. This roadmap defines the short-term and long-term action plan, responsibility and actions of related corporate functions, schedule, theoretic information flow and some related supporting activities (Ex: recruitment or training). Lastly, the operational module transfers the roadmap as a detailed practical working flow. The working flow breaks down the required actions into some real working activities. It arranges and optimizes the I/O network of all activities and integrates them into the actual working process of the company. Additionally, some modifications required to optimize this integration of the actual process will be analyzed. To ensure the information circulation between the three different levels and to verify the status, some interfaces between the three modules have been identified, such as translation from the strategic indicators to operational control indicators.

8.3.2 “Bottom-up” scenario

The “Bottom-up” scenario presents how operational practice affects and implements strategic decision-making. Although the strategic module has identified the global tendency of the technical development, some innovative works in this industrial sector and the new careered human knowledge could bring some new technologies into the company. These additional inputs might directly modify the state of knowledge and know-how of this company. In line with the development of new technology and knowledge, the company’s capital is consequently continuously modified to reflect this update.

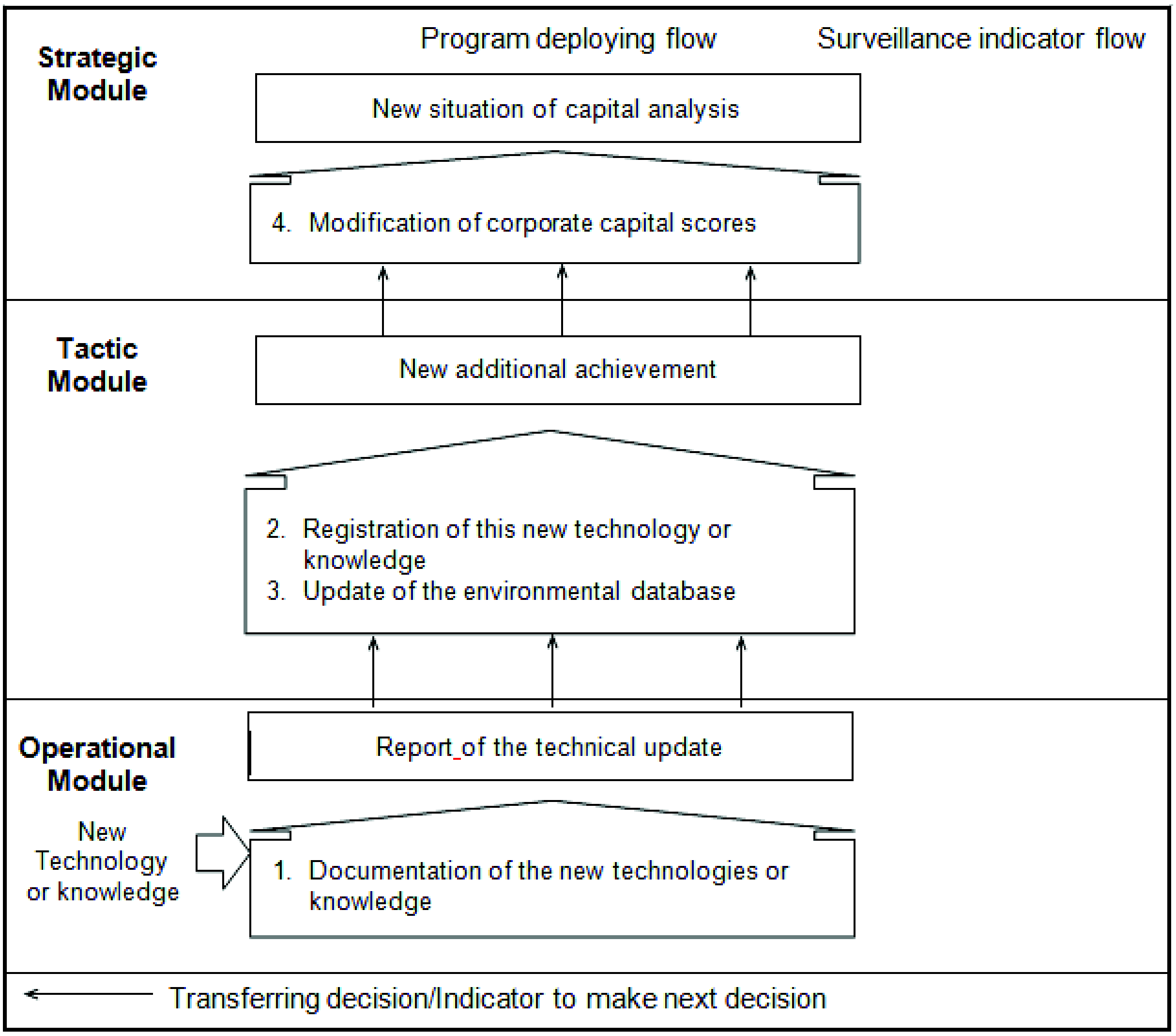


Figure 8-4: Work flow and decisional transfer of "Button up" scenario

This scenario starts from the operational module, and begins when new knowledge and new competences are detected. These new knowledge and competences are then transferred to the tactical module, which registers them in the method database. If this occurs, the update can be marked as a new achievement. In this case, the strategic module modifies the corporate capital scores to reflect this update in the corporate situation.

8.3.3 "Middle-two sides" scenario

The "middle-two side" illustrates the scenario that resolves the operational disturbance from some emergent requirements. The emergent requirements mean that the company or certain projects are required to treat some sustainable topics which have not yet been planned in-company. These requirements also present particular needs for some neglectable topics from the strategic level. For example: specific requirements of dismantling process for the product category, which is outside the legislation area. If necessary, the treatment of these topics may answer requirements. Furthermore, this can update and complete the corporate knowledge and competence level, which may affect future strategic decisions.

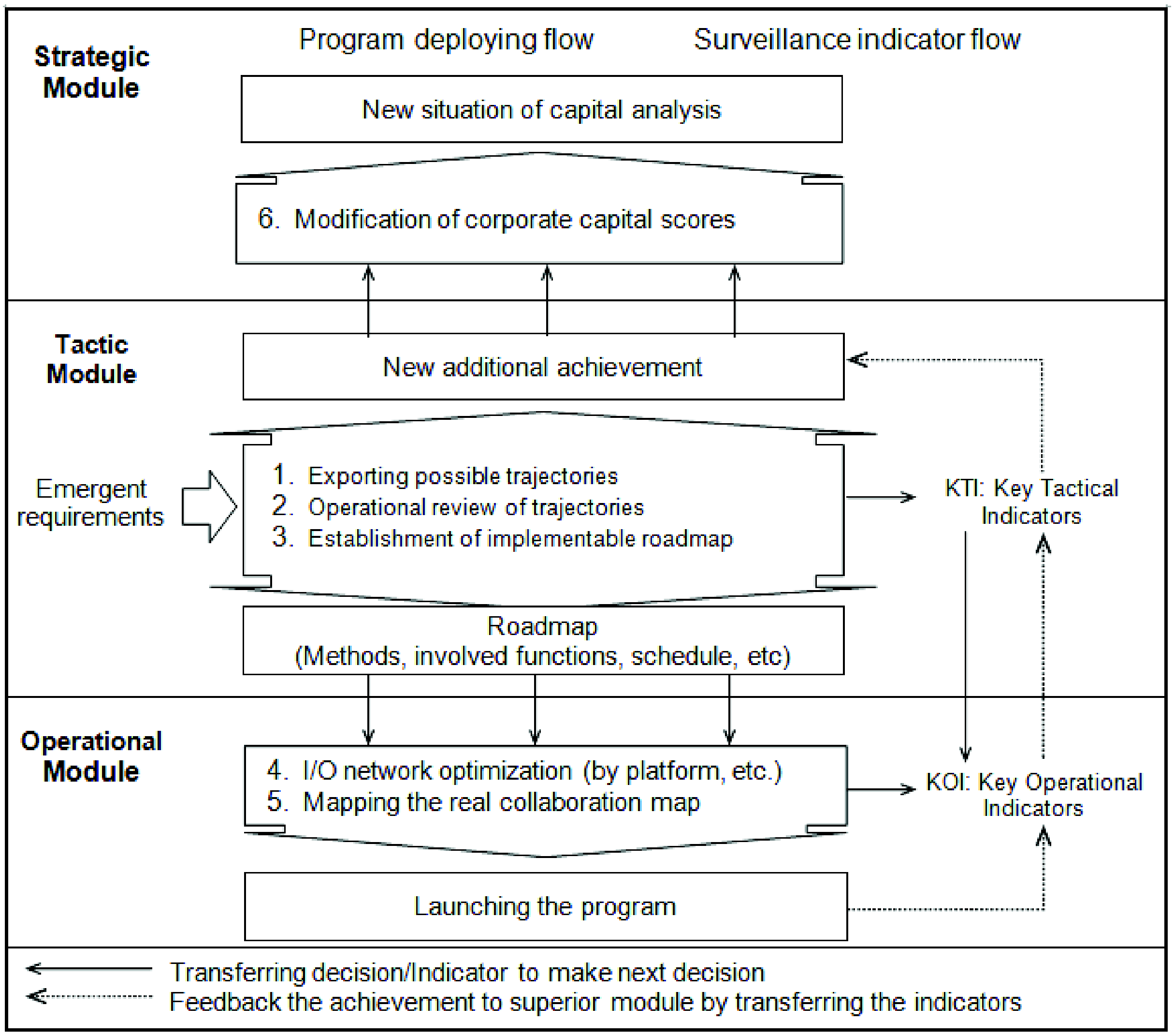


Figure 8-5: Work flow and decisional transfer of "Middle-two sides" scenario

This scenario starts from the tactical level. The managers decide if the company needs to answer these requirements. If yes, the tactical module analyzes the needs to explore the applicable direct methods or trajectories. Depending on the actual knowledge situation, the tactical module identifies an adapted planning. This plan will be transferred to the operational module to map the information exchanges needed to facilitate collaboration among designers. Finally, following the surveillance indicator system, the tactical module synthesizes the new additional sustainable achievements. Based on this achievement, the strategic module modifies the corporate capital scores to reflect this update of the corporate situation (knowledge level, experience).

8.4 Conclusion about the "vertebral column" model" and the applicable scenarios

Based on a literature analysis in previous chapters, this chapter states that a better circulation between the different functions in company could improve the integration of sustainable issues. Therefore a "vertebral column" model has been firstly proposed to provide a holistic definition about the responsibilities of three hierarchical modules: strategic, tactic and operational modules. The three modules cover the total corporate activities from global corporate development level to product realization level. And each level is addressed to different and complementary stakeholders in the company, in line with their own activity and expertise. In addition, the interactions between each module have been defined at their interfaces to establish the coherence between the three modules.

Meanwhile, based on the responsibilities of each module, three applicable scenarios have been proposed to describe the movement of decisional flow. Facing different situation, the initial decision could appear on every module. The "top-down" scenario describes the classic strategic mapping and deploying process. The "strategic module" initializes the environmental consideration and deploys the strategic decision to other two modules. But facing the emergency requirements and some particular needs, the initialization is from the "tactic module" (scenario "middle-two sides") to find out the particular solutions. This decision will be deployed to operational module and the results will be reported to "strategic module" to contribute the movement of corporate immaterial capitals. Finally, the "bottom-up" scenario describes the informational flow to register the new technologies and knowledge that have been integrated into the company.

The "Tactic" module, as a central module of this systemic approach is required to identify an implementable working plan by considering the coherence with strategic decision form top "strategic" module and the operational conditions from the "operational" module. In order to answer all requirements, the "tactic module" firstly defines a systemic environmental actions' cartography which registers a large volume of environmental expertise. This cartography is constructed by a depth analysis about more than 300 existing methods and industrial practices. Based on this cartography, tactic module could propose several different operational scenarios to release the strategic requirements. Meanwhile, depending on the "Gap Analysis", the dynamic corporate context and the concreted "strategic preferences" have been integrated into the selection of suitable solution. Finally, "Tactic module" provides a detailed roadmap to identify the working process and the support training to ensure the implementation. The details of “tactic module” will present into the next chapters.

IV

A NETWORK OF ENVIRONMENTAL ACTIONS TO DEFINE THE SCENARIOS FOR ENVIRONMENTAL INTEGRATION

According to the problematic and the requirements of "tactical" module, this part is to present an in-depth analysis result of existing environmental methods to re-construct several operational trajectories for fulfilling the corporate objective. Firstly, the environmental methods are considered as a "package" of a series of actions to resolve the environmental problem. So the first consideration presents the analysis at "operational action" level which could provide a detailed relationship between the environmental methods. This analysis creates a direct link between the corporate objectives and the environmental actions. And depending on the "interactions" among the actions, the company might generate several operational trajectories to answer an environmental objective

The chapter 9 and chapter 10 present how to break down the perimeter of existing environmental methods and set a standard actions chain for different environmental objectives. Furthermore, according to the informational and decisional flow, it redefines the interactions between actions to map a global action network – an environmental cartography. By analyzing over forty categories of methods of product and sit-oriented approaches, the chapter 9 proposes a systemic cartography of environmental actions which includes 46 environmental topics, 121 relevant actions and 186 interactions.

The chapter 11 presents the mechanism to pick out the right actions which will re-construct several operational trajectories. The summary of all potential trajectories could directly support the needs of "explorer" module. And the company might identify a suitable trajectory according to its dynamic context.

Chapter 9 - An in-depth analysis of environmental action[36] to be used at operational level

As the conclusion of chapter 8, an in-depth analysis of existing environmental methods and tools is necessary to be developed. As the requirements of "tactic module", this analysis needs to face a vast number of existing methods that embedded into two approaches: product-oriented and site-oriented approaches. Meanwhile, the technical and operational characteristics of all methods and the relationship among them will be analyzed to support the detailed working flow of "Tactic Module".

Before the launching of the analysis, this chapter summarizes some considerations about the analysis methodology. From the next paragraph, we indicate that the existing environmental methods are considered as the "package" of a series of operational actions to achieve the environmental goals. Furthermore, based on the analysis of the operational characteristics on operational level, such as the detailed operational requirements of each actions and the collaborative relationship among these actions, the environmental database could clarify the relationship between different methods, and improve the comprehension of the detailed necessities about material/immaterial resources. And finally, the author presumes that this analysis on operational level could directly support the integration of environmental activities into the company.

9.1 Considerations about environmental methods

The final objective of environmental integration is to resolve all environmental goals which are broken out for illustrating the aspect of corporate "environment" or "sustainability". This concept is the original purpose of all pre-formulated environmental methods and tools, sets of actions and all necessary resources and competence are organized into a pre-defined process in order to solve a concrete goal. In other words, the "environmental methods and tools" could be considered as a pre-defined "package" of a series of actions to achieve the environmental goals.

[36] "Actions", could be considered as a set of implementable units of each pre-formulated environmental method, presents an independent attribute (by the form of "deliverable") of the fulfilling of the concrete environmental target over a period of time.

Figure 9-1: The construction of environmental methods

In one side, the environmental methods and tools is designed for answering the concrete goals. The existing classification system, such as the proposition of [Bovea M.D., 2012], [Pardo R. J H., 2011] and [INP Grenoble, 2012] provides the correlation between the final environmental goals and the related methods. So the analysis about the existing environmental methods and tools might generate a complete list of actual environmental goals which could be considered as a set of available manners to construct the corporate sustainability. And inversely, once the company identifies certain environmental goals to be hitting, the related methods could be directly sought out to solve these goals. In another side, the packed actions and the related resources and competences could pilot the company how to prepare the implementation of thus environmental methods.

Facing the conclusion of chapter 4, it indicated that it's necessary to consider the detailed interactions among the environmental methods (implemented and to be selected) to dynamically identify the "complexity" of operation. But the environmental method is only a "package" of necessary actions, it is not the most basic unit to achieve an environmental goals. Especially, there are a series of actions have been embedded to meet a series of concrete targets, step by step. European Eco label defines 7 actions for labelling the product; [ISO 14040] identified the method - life cycle analysis includes 4 actionable steps: the identification of analysis scope, the establishment of environmental life cycle inventory, the environmental impacts calculation and finally, the environmental impact interpretation. And according to [Christensen P.N., 2005], [U.S. department of transportation, 2002], [Barringer H.P., 2003], the method - life cycle cost analysis could be separated into 7 independent steps . Referring to these definitions, the author believes that this in-depth analysis of existing environmental methods should break down the perimeter of existing methods and re-propose a series of operational actions for normalizing the working flow for answering environmental objective. This hypothesis includes two considerations:

1) We believe that a standardization of the actions' chain of each environmental method improves the comprehension of the detailed necessities about material/immaterial resources.

2) We believe that an analysis at "action" level provides a detailed mechanism of the "interactions" among different methods?

9.2 The analysis at "action" level could provide a detailed holistic view on environmental practices

As defined in previous chapter, "holistic" means that the method is a part of a global meta-system and is not disconnected from its contexts (economic, political, environmental and social), sources flows (material and immaterial) and reservoirs of value (such as people, knowledge, process) [Mercier-Laurent E., 2011].

As mentioned earlier, the environmental method is considered as a "package" of sets of actions. For each action, due to the difference of intermediated targets and the action natures (calculation or evaluation), the required operational conditions are changeable, such as the material/immaterial resources, the competence, the time and cost frame. So in order to make a detailed evaluation about the gap between the required operational conditions and the actual corporate context, and based on this evaluation to select the suitable environmental method, several literatures indicated that the integration of environmental method is necessary to identify the detailed operational conditions and exchange manner for each embedded action.

Generally, [ISO 14040, 2006] shown that for each step of LCA, there are some different requirements of collaboration from different stakeholders. And this international standard provides a detailed list of all different necessities of each action and it requires the company to consider them in the planning stage. [Donnelly K., et al., 2006] indicated that the implementation of environmental management is necessary to define the detailed environmental activities which are required by the selected environmental targets and methods. Several literatures about "POEMS" support this opinion that the holistic view of environmental collaboration of each activity is necessary to be explicated and organized in the planning stage [Jorgensen T.H. 2008], [De Bakker F.G.A, et al., 2002], [Erlandsson J., and Tillman A.M., 2009] and [Wagner M., 2007].

Meanwhile, [Knight P., and Jenkins J.O., 2009] pointed out that the application of selected methods or tools need a deep configuration to make the "compatibility" between the all contents proposed by methods and the real corporate context. By the examples of the application of the checklist, guidelines and Matrix life cycle analysis by MET Matrix, they explains that, the contents, the work timing, the interface for data exchange should be modified and re-defined to adapt the theoretical methods to the real competence and process environment.

[EPA, 2001] illustrated that the informational circulation among all related stakeholders (internal/external) should be carefully identified, organized, reviewed and upgraded for each step and activity for meeting the environmental targets. The "circulation" does not only treat the organizational structure of the informational and decisional flow (such as the forma and the typical content of data, the moment, manner and process of data exchange and the systemic IT system), it also needs to consider the abilities of data exchange. Globally, the company is required to make the corporate policy communication. And locally, for each step or activity, the company is necessary to make the cognition training of daily activities, competence support for dealing with the data, and individual development of the competences for using the related IT system or tools. In order to organize these works, [EPA, 2001] suggested a systemic and holistic overview of all related environmental steps or activity which have been required by the implemented environmental targets or methods, while they are in the planning stage.

As the summary of these above literatures, the environmental "action" is defined as the basic cellule, the analysis of the operational conditions, such as the informational flow, the competences necessary, the resources and operational time frame, will be established at "action" level. And this in-depth analysis of environmental methods could provide a detailed holistic view on environmental practices.

9.3 The analysis at "action" level could construct a systemic view on environmental practices

As the definition in previous chapter, the "systemic" means that every node of the system supports dynamic interactions within the whole system have been account [Mercier-Laurent E., 2011].

In order to treat the relationship among the environmental methods, it's necessary to fact that the manner of "interactions" among them. According to the above illustration, due to the environmental method involves a series of independent actions to treat about some different intermediate targets; and the environmental method is considered as a package of a series of standard actions. Facing to this situation, the author further consider if the environmental methods are absolutely independent and an action proposed by one environmental method could be shared for other?

Several developer of environmental methods indicated that some final or intermediate deliverables or outputs of its method could be profited for other utilization.

At first, the realization of environmental topic requires a chain of actions which provides a set of deliverables. But not all deliverables are necessary for other environmental topics. An obvious example is from the criteria of eco label. [ISO 14025, 2006] indicated that the criteria of "type II eco label" must be considered as the corporate rules to pilot and require the eco-design. [Houe R. and Grabot B., 2009] presented how to profit the eco label's criteria to guide the environmental performance improvement. And [Bonvoisin J. et al., 2010] referred the existing international recommendations and criteria to construct a guideline-based tool for supporting the realization of energy efficiency. These practices present some interactions between the topics "communication by eco label" and other topics. But exactly, Company doesn't need to launch a whole labelling process to construct its particular checklist, only the contents of criteria are usable.

Secondly, the whole process of environmental topics regularly needs to collect and treat several data about the system, product, functions or components. In order to make a clear correlation, it should explicit the interactions between type of data, deliverables and the manners of exchange [Jørgensen T.H., 2008]. And this more clear correlation could support to generate a detailed informational and decisional flow which is required by the previous problematic.

Furthermore, even the final purpose of certain environmental methods is not necessary to be implemented, but some intermediate actions are profitable and could be considered as a strong reference for others. A typical example is also from the eco label system. As the above presentation in chapter 3, the eco label system, especially, type I eco label, is one of creditable and efficient promotion method to communicate the product's environmental profile. But due to the limit of influence of the geometrical area and the complicated application process, the company might not select this scheme to communicate its product. But it's necessary to mentioned that the criteria and the testing methods of eco label award could be considered as a great reference for piloting the establishment of corporate environmental checklist [Toshiba], [HITACHI] or construct some other environmental methods or tools [Synergio, 2011]. According to the presentation of Japanese national eco label system – "Eco Mark", the criteria are set up and review by the group of environmental expert, the scientific bodies, the industrial delegates and the customer association. The final criteria could reflect the marketing hot points and the critical local environmental problems [website of eco mark], and the company could directly profit the whole or partial criteria to efficiently set up the corporate objective.

If all actions proposed by the method “eco label” are considered as an unique entity, it’s impossible to only pick out the “criteria and testing methods” of eco label award system for other environmental objective.

This consideration likes the concept of “recycling”. At the end of life of product, although the whole product is out of use, but the recycler could also pick out some components still useful. In order to make this sorting, the recycler needs a complete list of product’s components, the characteristics and the reusable state of each “component”. Meanwhile, the “compatibility” between the recycled component and the new product is also necessary to be analyzed.

Some actions could directly contribute to the achievement of other purposes in a different manner. In other words, this contribution from other methods provides a parallel implemented option which could totally or partial replaced an original action. Facing this situation, [Reyes T., 2007] summarized that this type of contribution might create different implementable trajectories to resolve a pre-defined environmental objective.

All previous presented environmental methods, was considered as a fixed “package” which is usually compromisingly designed for resolving a limited set of tasks. Since the actions are profitable for other purposes, it means the “action” is considered as a basic cellule which could be decomposed, replaced and recombined for meeting multiple tasks, does the environmental method could be “repacked” by a set of environmental actions proposed from different other method? Further, this reconfiguration will break the frontier of pre-formulate environmental methods and develop a particular trajectory. Therefore maximum flexibility and appropriate control is proposed to adapt the real corporate context and objectives [Reyes T., 2007].

Meanwhile, according to the suggestion from [Pardo R. J H., 2011], it’s necessary to consider how to inherit the developed competences and resources into company. This reconfiguration at “action level” can accomplish a large class of environmental tasks through inheriting the implemented action and only developing a small inventory of new actions.

The concept of “reconfiguration” is successful in some other industrial domain. For industrial robotic design, the whole goal is deconstructed by a set of independent actionable “modules”.

And a modular reconfigurable robotic system consists of various link and joint units with standardized connecting interfaces that can be easily separated and reassembled into different configurations. For manufacturing planning of facilities, each production line is considered as a "module" to construct a final process according to the technical and operational conditions.

Finally, similar with the previous consideration, the analysis of the interactions among different environmental methods will be sited at "Action" level. This in-depth analysis could provide a systemic view on environmental practices and generate even more operable trajectories for achieving the final goals.

9.4 Conclusion of the hypothesis

The existing environmental method has been considered as a "package" of implementable actions to resolve a concrete environmental target over a period of time. In order to provide a holistic and systemic view on environmental issues, in this chapter, two considerations have been proposed to demonstrate that an in-depth analysis of existing environmental method needs to be realized at "Action" level. Firstly, the dynamic operational necessities require a detailed analysis of the operational characteristics of each environmental action, which assists the industry to organize a global planning for all necessary resources and some back-supports (organize the internal training and promotion, etc.). Secondly, the environmental method might resolve several environmental targets and some environmental actions embedded into one method could contribute others. The detailed modulization of decisional flow and the interactions among them might encourage the sharability of implemented environmental actions and generate even more operable trajectories (regrouping the actions according to corporate context and needs) for achieving the final goals. The next chapters will illustrate the model and the results of this in-depth analysis of environmental methods at "operational action level".

Chapter 10 - An "operational cartography" of environmental actions"

As mentioned in previous chapters, with the presence of numerous environmental methods / practices and according to the dynamic environment of the company, a holistic and systemic view of environmental topics is necessary to organize overall corporate environmental activities. The global organization is not only focusing on the eco-design domain, it also requires integrating some typical activities from environmental management system. Facing this systemic requirement, one hypothesis has been indicated that a more profound identification of the existing environmental methods at operational level and the interactions between the environmental actions could support the establishment of this holistic and systemic perspective and generate even more possible trajectories to achieve the environmental objectives. To respond more specifically to the problem, a static base of existing environmental methods with specific characteristics and a predefined approach to analyze the correlation between the actionable steps of environmental actions are proposed.

10.1 Structure of "operational cartography of environmental actions"

The general structure of this "operational cartography for environmental integration" is composed by four parts: the environmental objectives (or goals), the environmental actions, the operational characteristics of each "environmental action" and the "interaction" among the actions.

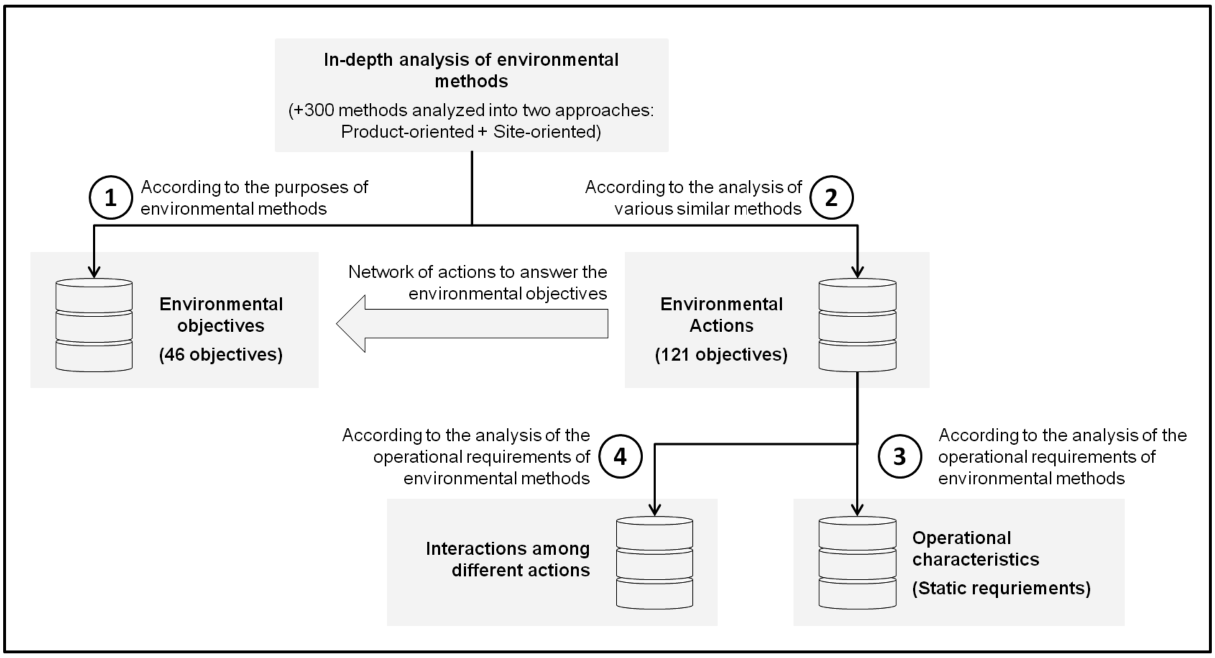


Figure 10-1: The structure of operational cartography for environmental integration

The “**Environmental Objectives**” presents the final environmental purpose which is proposed to describe the corporate sustainability. By analyzing the external or internal environmental needs, the company breaks down the environmental or sustainable aspects by sets of these topics. For example, facing the requirement of European directive WEEE, the company needs to implement some activities, like the “calculation of product’s recoverability rate”, the “organization of take-back system (or named as reversal-loop system)” and if necessary, the “design for recycling”. These three activities are named as “environmental objectives” in this cartography.

The generation of the list of actual environmental objectives has been established from the analysis of the purpose of all selected environmental methods.

The “**Environmental actions**” are independent attribute (by the form of “deliverable”) used to fulfill environmental target over a period of time by collecting and operating the necessary sources. A chain of actions is considered as a multi-steps process to resolve an environmental objective.

Existing environmental methods are also considered as the key element to generate the chain of actions and the relationship between the environmental topics and actions.

The “**operational characteristics**” are some descriptions about the conditions to implement an “environmental action”. For the “gap evaluation” between the theoretical needs and corporate context, the inputs, outputs, necessary competences are listed according to the analysis of existing environmental methods. Additional, if available, the time frame and the cost analysis of certain actions are listed also.

The “**interaction**” presents the movement of decisional flow among different “environmental actions”. Logically, two environmental actions are linked by “interaction”. This means that the previous one could provide whole or partial necessary inputs to release the second one. In this cartography, the “interaction” includes the original link which connects two actions proposed by a same environmental methods and the “new” link which connects two actions from different methods.

10.2 Generation of environmental topics

Till now, some authors proposed lots of classifications for environmental methods or tools [Brezet, 1997], [Robert K.H., 2000], [Baumann et al., 2002], [Janin M., 2000] and [Wong, Y.L., 2009] . According to these previous literatures review, a list of environmental objectives has been prepared in accordance with the following format:

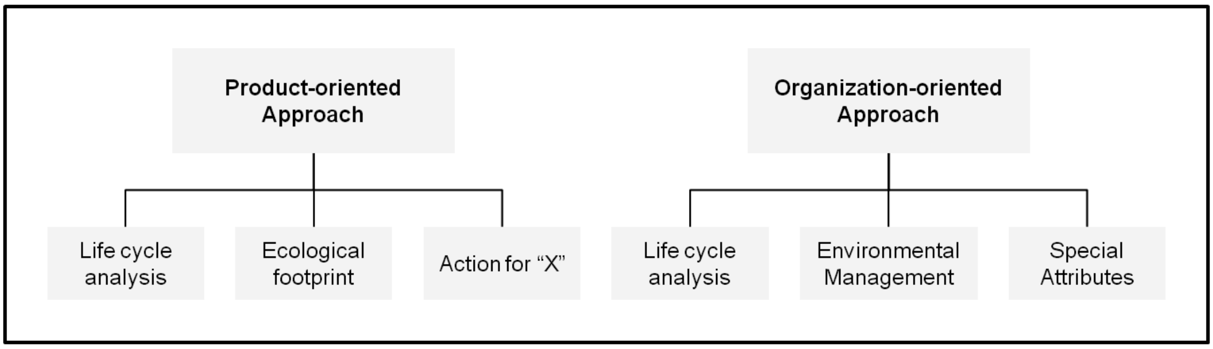


Figure 10-2: The structure of environmental methods classification

At macro level, harmonizing with the problematic, the environmental topics are firstly classified in two approaches: the product-oriented approach and the organizational-oriented approach.

Product-oriented approach focuses on the product’s environmental profiles, and the organization-oriented approach considers the environmental performance of all activities inside of the corporate frontier.

The product-oriented approach is separated into several different types in order to answer different corporate needs: the compliance of environmental requirements, the product’s life cycle analysis and life cycle cost analysis, the product’s environmental items prioritization, the environmental communication and the topics about design for X, etc. The whole list is listed as below:

Life cycle analysis
Product's life cycle environmental performance calculation (Quantitative)
Product's life cycle environmental performance evaluation
Product's life cycle environmental performance improvement
Product's life cycle environmental performance calculation (Qualitative/Semi-quantitative)
Product's life cycle environmental performance calculation (by checklist)
Product's life cycle environmental performance improvement (by checklist)
Actual product's life cycle cost analysis
Design for product's life cycle cost (Cost drive)
Product's Life cycle cost analysis for environmental improvement (Technique drive)
Ecological footprint
Product's streamlined life cycle environmental performance calculation
Action for "X"
Product's environmental legislation compliance
Identification of product's life cycle environmental nomenclature by PCR
Product's environmental items prioritization
Environmental guidelines exploration and identification
Reusable/Recyclable check
Recyclability rate calculation
Design for material recycling
Design for disassembly
Design for remanufacturing
Design of lifetime
Product's life cycle environmental performance declaration
Product's streamlined environmental performance communication
Product's environmental performance communication by eco label
Diagram validation the environmental improvement comparing with reference
Diagram comparison of environmental performance with reference
Generation of end of life instruction
Generation of improved end of life instruction

Table 10-1: The list of environmental topics of product-oriented approach

The organizational-oriented approach is also separated into several different types: the environmental management system, the reversal supply chain management, the collaboration with recycler, the process-oriented LCA and the best available technologies, etc. the whole list is listed as below:

Life cycle analysis
Process-oriented Life cycle environmental performance calculation
Process-oriented Life cycle environmental performance Evaluation

Process-oriented Life cycle streamlined environmental performance Evaluation
Actual process-oriented life cycle cost analysis
Design for process-oriented life cycle cost (Cost drive)
Process Life cycle cost analysis for environmental improvement (Technique drive)
Environmental management
Process-oriented environmental management system (Including the process-oriented LCA improvement)
Special attributes
Process-oriented legislative compliance
Best available technologies and other technologies
Logistic network and Stock management
Recycled material acquisition
Reverse and closed-loop supply chain performance evaluation
Reverse and closed-loop supply chain management
Green Supplier management
Product based supply chain management
Signature of the contract with end of supplier for waste collection and treatment
Collaboration with recycler to obtain primary end of life treatment data
Collaboration with recycler to improve the recycling performance
Process/organization environmental performance communication

Table 10-2: List of environmental topics of organization-oriented approach

After an analysis of the details of each method, three points should be emphasized.

At first, some environmental topics, such as the life cycle analysis and life cycle cost analysis, have been further divided by some precise topics in acceptance with different real needs. The life cycle analysis is divided as “life cycle environmental performance calculation”, the “life cycle environmental performance evaluation” and the “life cycle environmental performance improvement”, because the Life cycle calculation is enough to answer the requirements of some environmental topics, such as the environmental declaration program. If the company only declare the actual environmental profiles and do not release any eco-design, the topic about “evaluation” and “improvement” are not necessary. Inversely, the company could regroup these three environmental topics to realize a complete life cycle environmental improvement. And also, by similar reason, the life cycle cost analysis is divided as “technique-driven LCC” and “Cost-driven LCC”. The first is for evaluating the economic performances of new proposed technologies, and the second is focusing on the cost reduction.

Secondly, some environmental topics, especially, the life cycle analysis, are further divided by some different versions depending on the different manner of treatment. According to the nature of methods, the life cycle analysis includes the quantitative LCA, the qualitative LCA by checklist and qualitative LCA by matrix [Baumann et al., 2002], [Janin M., 2000] and [Wong, Y.L., 2009]. These different manners require different competences and sources, so in our environmental topics list, there are listed as three independent topics.

Thirdly, some environmental topics, such as the design for reuse and the design for material selection, are not listed as an independent topic. The reason it’s not listed because their functions/role could be equivalently treated by some others topics. For example, the reuse of waste product could be classified as two types: the entire reuse and the partial reuse. The entire reuse focuses on how to prolong the lifetime which has been analyzed by “design for lifetime” and the partial reuse could be equivalently considered as the “remanufacturing”. And also, the material is a “transverse” topic which is considered in several other topics. [Holloway L., 1998] summarized that the material selection might integrate the impacts on product’s cost, production process, the product weight for logistics and the hazardous substances. So initially, the designer needs to consider why they want to change and select a new material and then, act it by some specific topics (the LCC, the “process-oriented LCA + product’s life cycle environmental performance improvement”, the “logistics optimization” and the “guideline about hazardous material”).

Fourthly, some environmental topics, such as the “design for manufacturing”, are also be cleaned away from the environmental topics list. The reason is that this “Design for manufacturing” could be constructed by some interactions between the topics “manufacturing analysis” and “the product’s life cycle improvement”. The details of interaction will be presented in the following paragraph.

10.3 Methods to analyze the chain of actions of environmental topics

The environmental topics are listed based on the existing environmental methods. So equivalently, we presume that the process of each type of environmental method could be considered as the process for related topics.

The environmental method is defined as “a series of steps or actions, collect or operate the sources necessary, taken to resolve a specific environmental object”. And the environmental object is a new additional issue, which did not present a clear relationship with the classic product’s or organizational characteristics. Although for same type of method, different authors provide the different processes due to the different sources and competences required. In order to standardize them, two main methodologies are used.

At first, the ISO 14001 proposed PDCA (Plan-Do-Check-Act) methodology is considered and used for constituting the process about organization-oriented approach:

- **Plan**: set up the environmental objectives in acceptance with the corporate policy. In order to set up a suitable plan, the collection of certain necessary information is required as a preparatory step. According to the fixed objectives, identify the program for resolving the environmental issues.
- **Do**: implement the programs
- **Check**: monitor and measure the achievement of program against environmental objectives. The documentation and the registration of information are required.
- **Act**: the actions to make the continuously improvement.

For product-oriented approach, the harmonization with engineering process is a critical point. In this thesis, the approach of "V-Model" is considered as the reference of engineering process. The first reason for selecting this model is that this V-model is a conceptual model to produce a framework of products or systems development with providing a detailed action chains. This abstract description eliminates the impacts of the differences among various contexts. Secondly, this is a standard engineering model used by German and US government. It also harmonizes with the ISO 14062, the integration process of environmental aspects into product design and development.

The following figure illustrates a graphical representation of the systems development lifecycle by V-Model. It summarizes the main steps during the whole process of the engineering development. The left side of the "V" represents several steps about the decomposition of problematic and requirements, collection of necessary data, and the creation of development specifications. The bottom side presents the step of alternative design step to resolve the defined specifications. And the right side of the "V" represents the steps about the test activities, some integration, verification and validation.

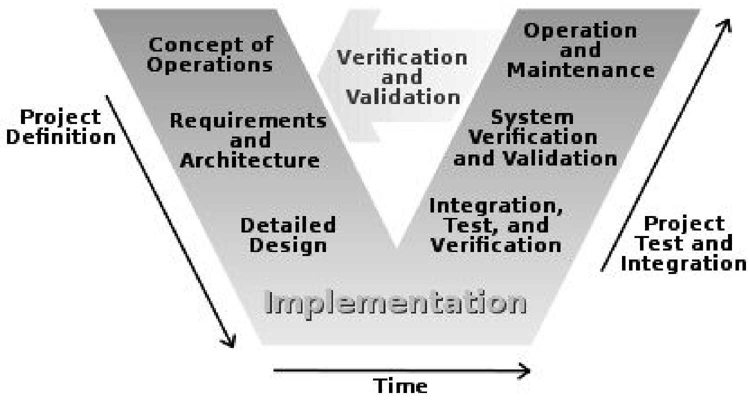


Figure 10-3: The graphical representation of "V-Model"

ISO 14062 presented a similar approach, which includes 6 steps. The only difference is to add the marketing launch and communication steps. In the first step, named as "Planning", ISO 14062 suggests the designer considering environmental aspects and life cycle thinking, making the analysis of the reference product, prioritizing the environmental impacts according to the benefits and feasibility etc. And then, in second step – "Conceptual design", it suggests the completion of product's environmental specifications by some design concepts and the results of reference analysis. After the "detailed design" and the step of "test/prototype", ISO 14062 commands to publish the environmental performance, consider the best use scenarios and the disposal manners. Finally, the last step "product review" suggests a construction of the expertise and environmental impacts data base for future work.

According to the process and requirements from "V-Model" and ISO 14062, a general methodology which includes 8 steps, is considered to generate the realization process of each environmental topic:

Step 1: Object – the object here means two senses. The first one is about the identification of hitting components, sub-assemblies, product or product family[37]. The second means the environmental objective selected which will be treated by following steps. The reference product is necessary to be identified also in this step.

Step 2: Collection – according to the object selected, collect all necessary information to support further evaluation and improvement.

Step 3: Calculation – depending on the information collected in previous step, the objective of this step is to indicate and evaluate the environmental characteristics which are used for describing the object's (product or organizational activities) environmental profiles.

Step 4: Evaluation – facing to the results contains various environmental indicators (if existing), this step is to take a priority and identify which ones should be prioritized resolved. Additional, the evaluation results might be documented for integrating the environmental issues into product design specification or engineering plan.

Step 5: Relationship – this step is to find out the relationship between the selected environmental indicators and the product's technical or functional characteristics. This relationship shows the possibilities of environmental improvement.

[37] The product family means a group of products which have the similar technical characteristics and using functions. The difference among them does not lead to a significant different on environmental performance.

Step 6: Guideline – facing to the possibilities of improvement, this step is to alternately generate the new design about product's characteristics with the support from some guidelines, expertise database and the references.

Step 7: Validation – once the new design has been released, this step is to validate and ensure if the results achieve all pre-defined objectives.

Step 8: Communication – At the end of product's development, this step consider the declaration and the communication of environmental profiles. This step also includes the announcement for the best using manners and the disposal treatment.

The next paragraph presents an example from "life cycle analysis" to illustrate how to generate the realization process by this methodology.

It's necessary to mention that although ISO 14040 series identify a standard process of life cycle analysis which includes 4 steps: At first, identification of the "Goal and scope" and then, preparation of the Life cycle inventory (LCI), thirdly, take the "Life cycle impact assessment" by some proposed methods, lastly, the step of "Interpretation" to illustrate the impacts by the pre-defined environmental indicators. But typically, in practice, with the development of life cycle assessment (LCA) software, most of previous steps, especially, the life cycle inventory and life cycle impact assessment steps, could be supported by the pre-defined modules (database) and the embedded calculation methods in the LCA software. The life cycle inventory (LCI) database provides a simple and credible solution to identify the standard flow model and related elementary flow which allows the designer to access the secondary environmental data. And additionally, the primary data might be integrated by the modification of software's module. So facing this change, the process of LCA calculation in this database is proposed as the process of using the software.

So in order to normalize the evaluation process, a depth analysis of the existing LCA software has been launched. This analysis focuses on the existing software which includes the classic LCA evaluation, such as the "software SimaPro[38]" or the simplified LCA software, such as

38 Simapro: developed by PRé Consultants B.V., is a famous and worldwide-use quantitative life cycle assessment tool for all product categories. The main feature of this tool is the flexibility of life cycle inventory and impacts assessment methods. Multi-different types of methods have been involved. And the user could also easily define own method. The input-output database is also involved to evaluate the environmental impacts per sector based on economic flow. Beside of standard analysis, the quick one is also supported. The "life cycle costing" analysis is also supported.
Resource of Major information comes from the European committee website – joint research center *http://lca.jrc.ec.europa.eu/lcainfohub/toolList.vm* and Web demo of SimaPro introduction
http://www.pre sustainability.com/download/Webdemo/SimaPro_7_Introduction.htm

the “LCA-eVerdEE software[39]” which is a simplified version of LC inventory and pre-defined analysis methods.

In acceptance with the above “8 steps methodology” and the user guides of the software, the process for realizing the “product-oriented life cycle analysis” is described as:

Action 1. Identification of analysis scope and function unit

This action is related to the “step 1” of above methodology. According to ISO 14040, in the action, the designer needs to clearly define the product system to be studied, the functional unit, the system boundary, allocation procedures, the data requirements and some assumptions. If this LCA is to compare between the new design and a reference product, the reference should be also identified in this action.

Action 2. Identification of product’s life cycle environmental nomenclature by designer

This action is related to the “step 2” of above methodology. In acceptance with the definition in previous action, the main purpose of this action is to collect and identify all necessary definition to describe the product’s life cycle situation. With the existence of LCA software, this collection and identification don’t need to touch detailed elementary flow as a standard life cycle inventory; but it should complete the information to help the identification of life cycle scenarios. For example, this nomenclature should explicit the end of life treatment scenarios (Reusing, dismantling, shredding, energy recover or landfill, etc.) of each component this definition could pilot the module assignment in next action.

Action 3. Selection of marched “pre-defined modules” and method in LCA software

According to product’s life cycle nomenclature, this action requires the designer selecting the most marched “pre-defined modules” in LCA software to completely establish the product’s life cycle model. For each selected module, the characteristics should be identified. The life cycle impact assessment method needs to be also identified in this action.

Action 4. Calculation of product’s life cycle environmental performances

If all necessary modules have been selected and characterized, the LCA software could automatically calculate the life cycle environmental performances. The “action 3” and “action 4” are related to “Step 3” of above methodology.

Action 5. Identification of significant impacts contribute product’s life cycle items

Basing on the results of life cycle environmental impacts calculation, this action requires identifying the cause of the environmental impacts, the significant items of product’s life cycle and the contribution ratio of each life cycle element. Some functions of LCA software, such as the method of “Normalization” and “Tracking Back system” could support this action.

Action 6. Documentation of evaluation results and improvement recommendation

[39] The eVerdEE, developed by ENEA - Italian National Agency for New Technology, Energy and the Environment, is a quantitative simplified life cycle assessment tool for all product categories, both the industrial and agriculture users. In order to simplify the utilization, with the support of individual database, the process for identifying the system boundaries, the elementary flows and the environmental impacts of each process or material have been simplified and pre-elaborated. Users only fill in the quantity of the inputs/outputs and choose a corresponding module from the database to finish the life cycle inventory.
Resource of Major information comes from the European committee website – joint research center *http://lca.jrc.ec.europa.eu/lcainfohub/toolList.vm*

This action requires a data registration to save the evaluation results and the improvement recommendation. This action is independently listed because it’s directly required by some directives and standards, such as the EuP directive, the ISO 14001 certification, etc.

Action 7. Identification of product environmental improvement specification

This action and “action 5 and action 6” are related to the “step 4” and “Step 5” of above methodology. Based on the evaluation results of actual product’s life cycle environmental impacts and some environmental improvement recommendation, this action requires identifying a specification to fix the improvement objectives. This objective includes the final targets of this improvement, the environmental indicators should be considered and the list of related life cycle items will be optimized. The items are not only be caused by product designer, but might be also contributed by the supplier management, the manufacturing process, the logistic network and the end of life management.

Action 8. Alternative eco-design/process improvement

This action is related to the “Step 6” of the above methodology. According to the product’s environmental improvement specification, the alternative researches will be done to resolve the environmental concerned problems. To resolve these topics, some guidelines, expertise and references are necessary to provide the potential solutions. The LCA software could alternative calculate and verify the new environmental profits of these improvements.

Action 9. Formulation of improved product’s life cycle environmental nomenclature by designer

After the alternative eco-design, the product’s characteristics, functions or life cycle scenarios have been improved. The main purpose of this action is to re-identify all necessary definition to describe this new improvement.

Action 10. Calculation of improved product’s life cycle environmental performance

If all necessary modules have been selected and characterized, the LCA software could automatically calculate and validate the life cycle environmental performances. The same calculation method has to be used into this action to ensure the final comparison.

The “life cycle analysis” does not provide the manners for environmental communication, although it offers the results of calculation and evaluation. The communication issues will be considered in other environmental topics, such as the “communication by eco label” and the “declaration of environmental profiles”.

It’s necessary to be mentioned that the “life cycle analysis” has been divided in previous paragraph into three topics: the “life cycle environmental performance calculation”, the “life cycle environmental performance evaluation” and the “life cycle environmental performance improvement”. So finally, the “action chains” of these three topics are shown as below:

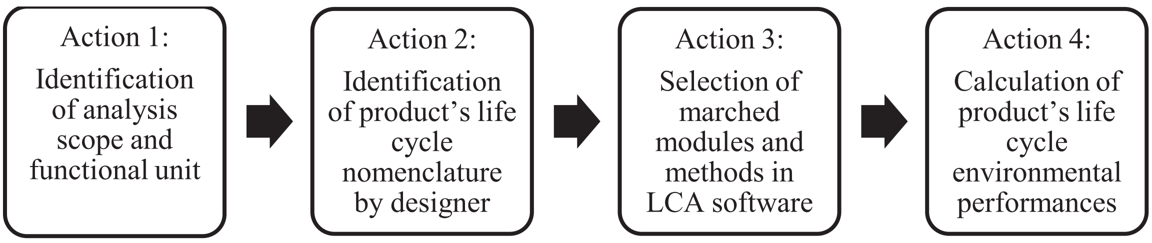


Figure 10-4: Action chain of Product's life cycle environmental performance calculation

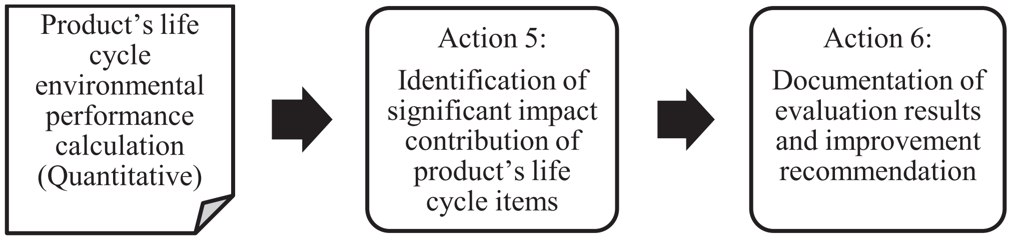


Figure 10-5: Action chain of Product's life cycle environmental performance evaluation

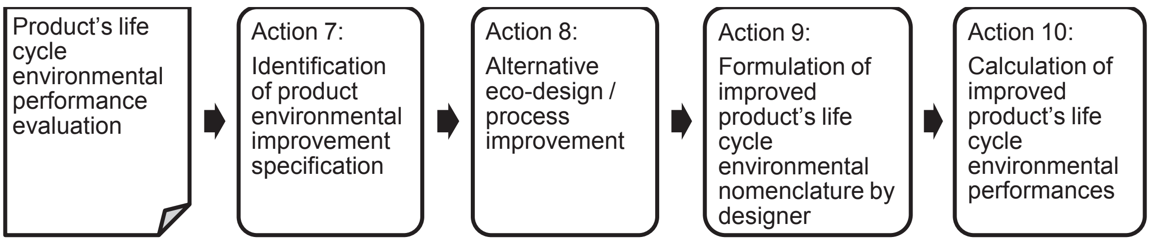


Figure 10-6: Action chain of Product's life cycle environmental performance improvement

Meanwhile, the software user guide and its training materials support the author to normalize the informational flow during the action chain. Here, the first action 1 requires "the identification of the analysis scope and the functional unit". According to ISO 14040, in the action, the designer needs to clearly define the product system to be studied, the functional unit, the system boundary and some other assumptions. In order to release this work, the company should take the knowledge about "what is the analyzed boundary and functional unit and how to identify them". Meanwhile, facing the vast number of commercial references, especially, for large-size Company, some companies and PCRs [PEP Eco Passport, 2010] prefer releasing only one LCA which could cover all similar products. So in this action, it's necessary to identify a "representative product" to be analyzed which could represent a whole product family.

Action 1: identification of the analysis scope and the functional unit	
Description: This action defines which product or product family will be covered by this analysis. According to the scope definition, a functional unit should be specific to pilot the future work.	
Inputs	**Outputs**
List of products covered;	1) The analysis scope (how many product's family could be defined) 2) Definition of functional unit
Competences: 1) The knowledge of identification of product family (If need) 2) The knowledge of the functional unit and how to identify the functional unit	

Table 10-3: The operational necessities for Action: identification of the analysis scope and the functional unit

The detailed description of operational necessities for the other environmental actions is presented into Annex.

Finally, all related environmental tools, the list of the existing LCA software in this case, have been also registered. The following table summarizes 20 existing LCA software. According to the analysis report of [Jönbrink A.K. 2000], this table notices also some operational characteristics of them, such as the license cost, the duration for learning the software and the applicable product's area. Once the company defines to release these actions to answer the environmental objectives, the list of available tools could further support the selection of the suitable tools and the development of the necessary knowledge.

N^o	LCA software	Proprietor / Developer	License cost*	Learning duration*	All products*
1	AIST-LCA Tool	AIST Japan	1	2	Y
2	Eco-selector	Granta Design Ltd		2	Y
3	CUMPAN	Hohenheim Universitat/Daimier Benz	3	2	Y
4	Eco-it	Pré consultants	1	1	Y
5	Ecolab	Nordic Port AB	2	2	Y
6	EcoScan	Turtle Bay	1	2	Y
7	EverdEE	ENEA - Italy			Y
8	EIME	CODDE	2	1	N
9	EPID PC-Tool	Danish environmental protection agency	1	3	Y
10	EPS	Assess Eco-strategy Scandinavia AB	2	3	Y
11	Gabi	PE International GmbH	3	4	Y
12	Green-E	Ecointesys			Y
13	LCAiT	Chalmers Industriteknik, Ekologik	2	3	Y
14	JEMAI-LCA Pro	AIST Japan	1	2	Y
15	KCL-ECO	KCL	2	3	Y
16	SimaPro	Pré consultants	2	2	Y
17	LCA Support	NEC corporation	2	2	Y
18	TEAM	Eco bilan	2	2	Y
19	Boustead Model	Boustead consulting	4	2	Y
20	Umberto	ifu Hamburg GmbH	2	3	Y

Note: The license cost code: classify by the number (from 0 to 5) according to a single software license:
Per license (Unit: EURO) per year
0: Free; 1: <1000 €; 2: 1000-5000 €; 3: 5000-10000 €; 4: 10000-20000 €; 5: >20000 €
The duration of learning code: classify by the number (from 0 to 4) according to the official learning times:
1: < 2 hours; 2: < 1 day; 3: < 1 week; 4: < 1 month; 5: Other
All products: classify by the product categories supported by this LCA software:
Y: All product categories supported; N: Certain product categories supported
The information and references are from the official website of LCA software and the report of Sirii -Swedish Industrial Research Institutes Initiative – "LCA software survey", September 2000

Table 10-4: List of LCA software

Finally, this environmental cartography registers more than 300 environmental tools which contribute to the achievement of 46 environmental approaches. There are 26 approaches for product-oriented environmental issues and 20 approaches for site-oriented. Similar with the above definition for LCA, this environmental cartography set up a normal chain of actions for each approach.122 environmental typical actions have been proposed. In order to realize each action, the description of the purpose, a list of inputs and outputs and the necessary competence have been also described to support the environmental integration. The detailed action chains definition of other environmental topics are listed into Annex.

10.4 Construction of the interactions among the environmental actions

The interactions among different environmental actions depend on the analysis and re-classification of existing methods and industrial practices.

There are some necessary inputs and sources required for launching an action. And also, the output of such action provides the entire or partial necessary inputs of next action. So based on this “Resource-based” model, there are three types of interactions between environmental actions that one action could provide the entire or partial inputs for releasing the others:

“**Inheritance**” relationship: This type of relationship is to present the correlation between two environmental actions that one action can provide the entire necessary input to another.

The following figure shows an example of the interaction of “inheritance”. Based on the results of life cycle impact calculation, the designer or environmental expert can identify which impact or indicator is most significant. The quantitative software’s results, such as the inventory and the histogram of environmental impacts, could completely support this identification. So in this environmental cartography, the “interaction” between the “Quantitative LCA calculation” and the “identification of life cycle significant impact” is defined as “inheritance”. Meanwhile, the qualitative life cycle impact analysis could also support this identification. The “Matrix LCA” and some environmental check lists clearly make the order of selected environmental impacts by the “High-Medium-Low” level which also could support the identification of significant impacts. And then, some streamlined LCA, although if they only focus on one environmental indicator is valuable to order environmental issues. Such as the carbon footprint, the results of this footprint present in which life cycle phase, it discharges the largest volume of carbon dioxide and this data can be considered as a reference to guide the further life cycle improvements.

So, in this environmental cartography, in order to “identify the significant impacts”, there are three possible previous actions, “quantitative LCA”, “qualitative LCA” and “Streamlined LCA”. The “interaction” between them is in form of “inheritance”.

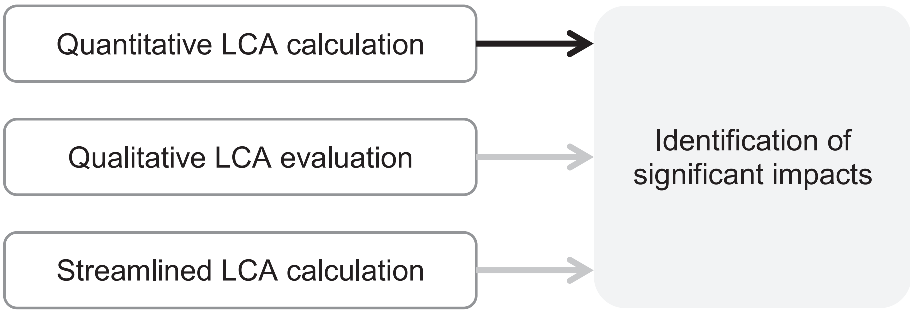


Figure 10-7: The "inheritance" interactions

It's necessary to be mentioned that although the nature of data might be different (quantitative or qualitative), as long as the recipient is compatible, the inheritance relationship is also validated. Here, the "black arrow" and "gray arrow" is to present that these three actions are parallel; whichever could completely drive the next action.

"**Completeness**" relationship: This type of relationship is to present the correlation between two environmental actions that one action provides a partial necessary input to another.

The appearance of this type of interaction is due to the recombination of environmental topics and the related action chain. Practically, the outputs of one environmental action can not completely drive the next action. It's necessary to involve the outputs of other actions. An example is from the "identification of targeted parts for product's remanufacturing". Firstly, based on the technical and economic consideration, it's necessary to make the "reusable check" of whole product or certain components. Some indicators, such as the quality of these parts at end of life, the quantity of the parts to be recycled, the lifetime for second life cycle, etc, need to be evaluated. But this evaluation is not enough to drive the identification of the remanufacturing, because the valuable is not a single indicator to affect the remanufacturing, the disassemblability at end of life is necessary to be focused on. So finally, only combining the outputs of these two above actions, the environmental data is enough to drive the next identification for remanufacturing. This type of "interaction" is called "completeness".

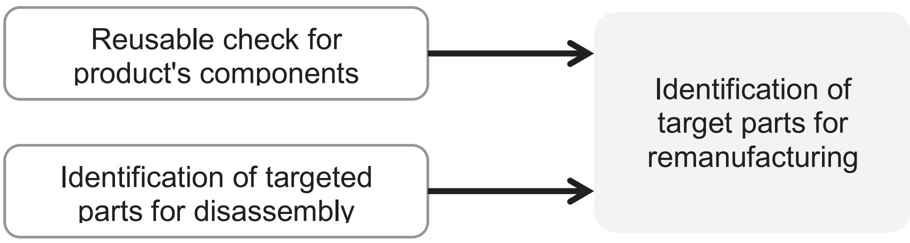


Figure 10-8: The “completeness” interactions

Here, in this figure, there are two “black arrows” which are two mandatory inputs for the next action.

“**Contribution relationship**”: The two above types of “interaction” present the mandatory informational flow between two actions. Now, the third type of relationship is to present the correlation between two environmental actions that one action provides some unnecessary but useful additional inputs to another. Here, “unnecessary” means the input is not critical required, but the existence of this input might optimize the quality of inputs or complete the information. A typical example is the integration of primary production data to complete the product’s environmental inventory. Practically, because of the existence of secondary pre-defined modules in LCA software, these environmental data are not mandatory. But if this data is available, and the LCA analyzer integrates them for modifying the software’s modules, it could produce a higher quality of product’s LCA and ensure a better competitive analyzing result (If the performance in production is better than average level).

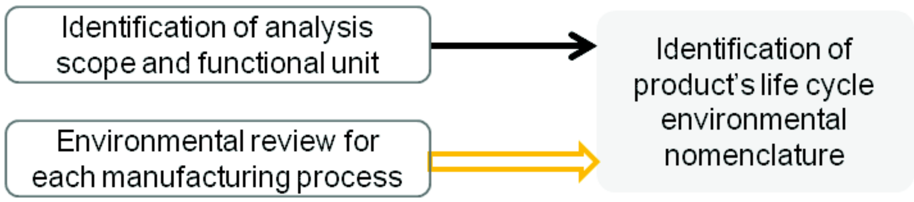


Figure 10-9: The “Contribution” interactions

The above figure presents that in order to prepare the “environmental inventory”; the mandatory previous action is the “identification of the analysis of scope and functional unit”. The interaction between them is presented by a “black arrow” which means the “inheritance” relationship. Additional, the “environmental review for each manufacturing process” is voluntary and it only contributes the data quality of the inventory. So the interaction is in form “hollow orange arrows” to present the “contribution” relationship.

10.5 A systemic cartography of the network of environmental actions

By the construction of the environmental action chain for each environmental topic and the interactions among them, finally, we propose a systemic cartography of the network of environment actions in order to support the systemic organization of environmental program for company.

The structure of this systemic cartography includes three elements: the environmental topics, the environmental actions and the arrows that illustrate the action chains and the interactions.

The environmental topics list is coherent with the list in paragraph 9.2, including 46 different topics, 20 topics for organization-oriented approach and 25 topics concern the product-oriented approach. The last topic, the “eco design for package”, although the actions could be covered by above 25 product-oriented approach (due to the package could be considered as an independent product), it’s listed also here to remind the user these is some potential additional requirements on accessories.

For each topic, the related actions to resolve this topic are ranged in the right side of same line. The order of these actions is acceptance with the order of steps presented in paragraph 10.3. In order to simplify the exploration and the description of interactions in future, a coding system for each action is proposed. The code includes two elements in form “X.Y”. The “X” presents the number of action series (from 1 to 14) and “Y” presents the yth actions analyzed and integrated in this cartography. It’s necessary to mentioned that the definition of “action series” here is without any operational means, which is not acceptance with the “action step in previous paragraph”, it’s only for coding the action.

The arrows, which string together the environmental actions in same line, present the process of working flow to resolve the topic. The arrows link across the actions from different lines present the interactions. In order to present different group of inputs, the different colors of arrows are proposed: the black and gray arrow presents the “Inheritance” and “completeness” relationship, and the gray arrows further mean the several parallel inputs which could totally replace the black arrows. The hollow orange arrow presents the “Contribution” relationship. The following figure shows an overview of this cartography.

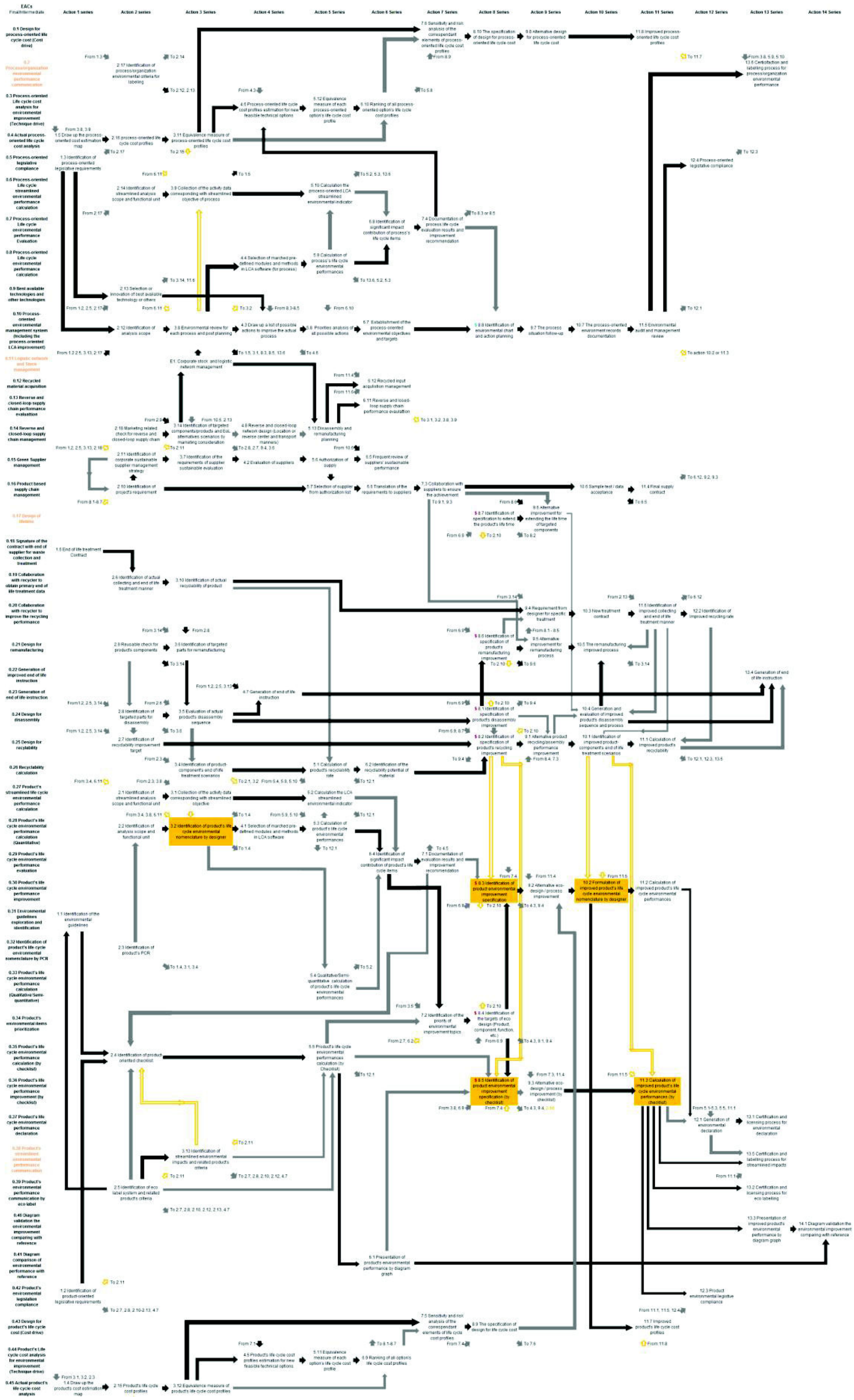


Figure 10-10: The systemic cartography of environmental actions

10.6 Discussion and conclusion about the construction of the cartography

From the illustration of previous paragraphs, this cartography here prepares a holistic and static overview of environmental issues, embedding the product-oriented issues and organization-oriented issues.

For each approach, this cartography tries to collect a more complete list of environmental topics. These topics are collected by the vast analysis and reclassification of existing environmental methods and industrial practices. Finally, there are 46 topics proposed, which include 20 topics for organization-oriented approach and 26 for product-oriented approach. So inversely, we presume that the use of these environmental topics or the combination of these topics could resolve the real environmental problems. Depending on a vast analysis of bibliographies, for each environmental topic (details are listed in Annex), a working process, with a chain of environmental actions is proposed. Each action is created for one specific objective (although it might require the analysis of various elements) and finally, 122 typical actions have been created. The framework of these working processes constructed by the actions is in acceptance with the mechanism of product design & development (V-Model) and environmental management (proposed by ISO 14001).

Building further on this cartography, a detailed description about the operational conditions of each environmental action is prepared. Based on the "resource-based" points view, the actions are described by four elements: the objective, the necessary inputs, the outputs and the necessary competences. In order to simplify the operational process, the form of inputs and outputs are detailed described. The related methods and tools are listed also to complete the information.

The last contribution of this cartography is to create three types of static interactions between different environmental topics at action level. This definition of interaction at action level allows the de-correlation between the environmental topics and related actions, and it ensures the flexibility for the generation of realizable process of real problem by any possible actions, without the limit and consideration at environmental topic level. A direct example comes from the establishment of criteria for eco-design. The industry could only refer the contents of criteria without following the processing of labelling. Beside of this reference, there are some parallel possibilities, such as the reference and checklist of type II eco label, the checklist of life cycle analysis, the requirement from the laws or the corporate auto-definition. So the definition of the action chain for each environmental topic could be considered as a process of “fragmentization”. And the network of interactions, which re-constitutes the “fragments”, allows the company to explore various realizable trajectories to resolve the specific problems. Meanwhile, the holistic point of view, which includes 46 environmental objectives of product-oriented and organization-oriented approaches, ensures a systemic and larger consideration of the possible application scenarios. And the detailed description of each action further ensures the possibility for ranking and selecting a suitable trajectory according to dynamic context.

Chapter 11 - Generation of suitable trajectories to answer the corporate environmental objectives

With the contribution of previous holistic and systemic cartography of environmental actions, the chapter is to illustrate how to profit this cartography to generate several possible operational trajectories. Each trajectory presents a particular and independent way to answer environmental objectives. The company can classify them and select a suitable one depending on its dynamic corporate context.

In next paragraphs, firstly, a "tracking back" mechanism will be proposed to pick out the right environmental action to re-construct the trajectory. Meanwhile, some operational conditions will be added to limit the exploration of the environmental actions. The objective is to make a more systemic and efficient hitting for answering the corporate needs. According to the "strategic preferences" and the "operational context", the company evaluates these trajectories and selects a suitable one. Finally, a roadmap will be set up to implement the selected trajectory into the company. All of this mechanism constructs the "tactic" module "of the environmental "vertebral column" model presented into chapter 8.

11.1 The "Tracking-back" mechanism

In chapter 10, a systemic and holistic cartography of environmental actions has been proposed. This cartography broken down the perimeter of formed environmental methods by a series of operational actions, and it regrouped them by three types of "interactions" according to the working flow between them. Here, a "tracking back" mechanism is presented to explain how to pick out the right actions to re-construct several operational environmental trajectories for fulfilling an objective. As its name implies, the basic method of "tracking back" is firstly to find out the last action or actions whose output could directly answer the needs and secondly, to explore all possible previous actions to construct a chain of actions.

Here, there are two definitions to remind:

The definition of "environmental action", it's an independent attribute of the fulfilling of the environmental target over a period of time by collecting and operating the necessary sources". This definition presents that once one action has been released and achieved, the related "specific environmental object" has been resolved.

The definition of the interactions and the action chain is based on the “resource-based” point of view which means that the outputs of previous action provide entire or partial inputs of next action.

Each environmental action is considered as an independent operational unit which is driven by inputs and generates a set of outputs. And these outputs might drive several following actions which are linked by three types of interaction. This type of multi-interactions ensures the possibilities to achieve a concreted objective by several different ways.

According to these two above definition, in order to generate the summary of all possible implementing trajectories for answering the environmental objectives, a “Tracking back” mechanism is proposed. According to the proposed cartography, at beginning, the first step is to find out the object action or actions group could directly answer the requirements from environmental objectives. There are two manners to hit the right action. Firstly the company can consider the description the environmental topic which directly presents the proposition of the final related environmental actions. For example, if the company wants to calculate the products life cycle impact, the environmental topic “Product’s life cycle environmental performance calculation (Quantitative)” seems to be a right choice. Or the company wants to integrate the recycled material into product; the environmental topic “Recycled material acquisition” might directly answer the needs. Once the company identifies a relevant environmental topic to answer the objective, the last action in the same line of cartography is considered as a targeted action.

Once the object action has been defined, this mechanism requires looking for all previous action of this object according to three types of “interaction. If there are multi-parallel previous actions (the “inheritance” relationship), it means that there are multi-possible ways for resolving this objective. The name of actions and related environmental topics of thus previous actions will be registered to describe the different operational scenarios.

And alternatively, the mechanism traces the previous actions of these new funds again till the initial one which don’t have any previous. And, the footprint of this exploration could construct a complete operational trajectory, from the first action to last one. Finally, this mechanism summarizes all fund trajectories to generate an operational “scenarios map” which presents a systemic dashboard to all different way to resolve the corporate environmental objectives.

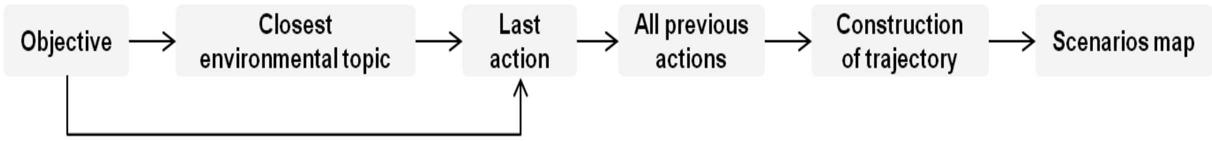


Figure 11-1: The process of “Tracking back” mechanism

11.2 A “DEMO” of exploration

In this paragraph, a demo is presented to illustrate the generation of operational trajectories by “tracking back” mechanism. In order to make a clear description, this paragraph presents the mechanism with the environmental objective: “embedding the recycled materials into new generation of product”.

For resolving this problem, we hunt out the environmental topic “Recycled material acquisition” that could directly answer this objective.

“The recycled material acquisition is an effective policies and management system to resolve the highly uncertain nature of quantity, quality and timing of returns for recycled materials [Ilgin M.A., 2010]. The uncontrolled products’ acquisition leads to a high degree risk of customer’s un-satisfaction and low quality level. This acquisition management system could be divided as two types: the self-waste stream acquisition system and the market-drive acquisition system for no-original defined resources. For each type of sub-system, this system set up the multiple levels controlling process (strict criteria, the technical validation, the credit of input’s quality, the cash pay for high quality, etc.) which make the interface between the RL network design, production planning and controlling activities [Guide V.D.R., 2001].”

The implementation of this topic means that the recycled material has been embedded into the resource supply chain. So starting from this topic to generate all possible preparatory works is a closest choice.

His environmental topic only includes an action – “6.12 recycled input acquisition management” which should be considered as the object action. The number noticed “6.12” is the order number of actions in the environmental cartography. And the “0.12” is the order number for environmental topic. These numbers are only used for the registration of this information.

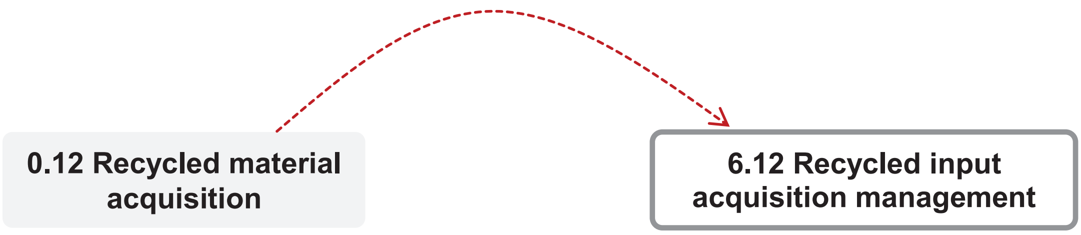


Figure 11-2: Identification of object action

Secondary, according to the “interactions”, in the cartography, this action links three previous actions:

- Action 5.13 “disassembly and remanufacturing planning”
- Action “11.4 Final supply contract”
- And Action “11.6 Identification of improved collecting and end of life treatment manner”

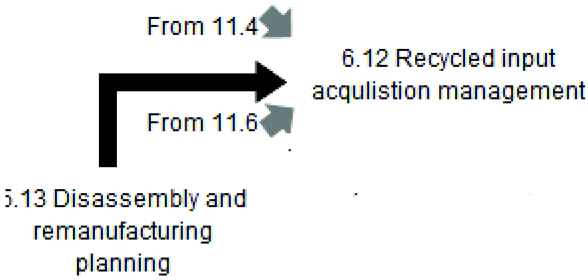


Figure 11-3: The previous actions of action “recycled input acquisition management”

The color code of these “interactions” is black and gray. As the definition of the “inheritance relationship”, the arrows mean these three previous actions are independent and each of them could entire support the necessary inputs of final action.

Linking with the related environmental topics, the first action 5.13 is proposed by the environmental topic “reverse and close-loop supply chain management” which illustrate the company charge the whole reversal supply chain by itself, including the identification of reversal target components or product, the establishment of reversal network and the planning of remanufacturing process of its own product. Specially, facing to the remanufacturing process, the company needs to consider the re-manufacturability of product, the advantage of the cost comparing with the premier material acquisition, the performance of the collecting system which focuses in the quantities, the delivery and the distance of collection, the quality of the reversal resources (Ex: the defection rate), the delay and the manners of production (including the inspection, the cleaning, the disassembly, the maintenance, the stocking management, the assembly and the final quality controlling) and also the corporate policies of enterprise [Sundin E., 2005], [Ilgin M.A. and Gupta S.M., 2010].

The second action 11.4 is proposed by topic "product-based supply chain management", which illustrates the process of supplier controlling. This choice could be considered as the company defines the reversal material as a normal resource/input which is embedded into the normal supply chain management. All processes of reversal activities are out of the corporate scope. As the normal inputs, the company verifies the global performance of supplier's production process and controls the quality, cost and delivery of final product. Because of the lack of collaboration with suppliers, the reversal flow is from the uncertain waste sources.

The third action 11.6 is proposed by topic "collaboration with recycler to improve the recycling performance" which illustrates the company accompanies the selected recyclers to finish and optimize some reversal activities, although all real activities are out of corporate scope. The company might participate in the researches with suppliers about the best available technologies of reversal process; the product design for recycling and remanufacturing or the consideration of marketing aspects to clearly indentify the recycling flow. Similar with the first scenario, the partial reversal flow is from the corporate own old product.

So initially, to resolve the problem about "using the recycled material in new generation of product", there are three parallel implementable macro-scenarios summarized as follow:

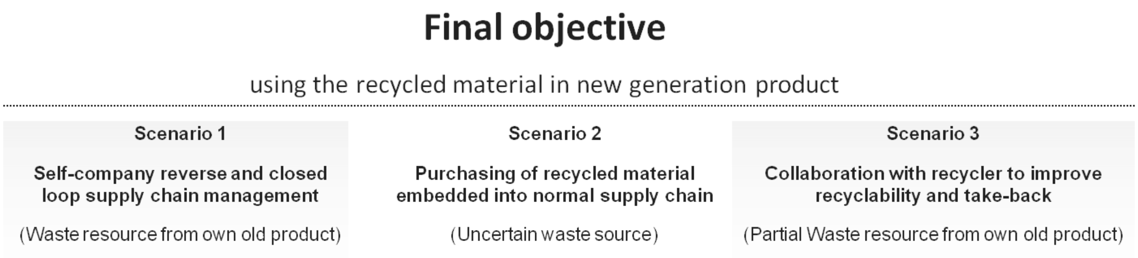


Figure 11-4: Three macro-scenarios for answering the objective about "using the recycled material in new generation of product"

Thirdly, starting from these three new fund actions, we explore again their previous actions. According to the cartography, the next paragraph presents the exploration for scenario 1.

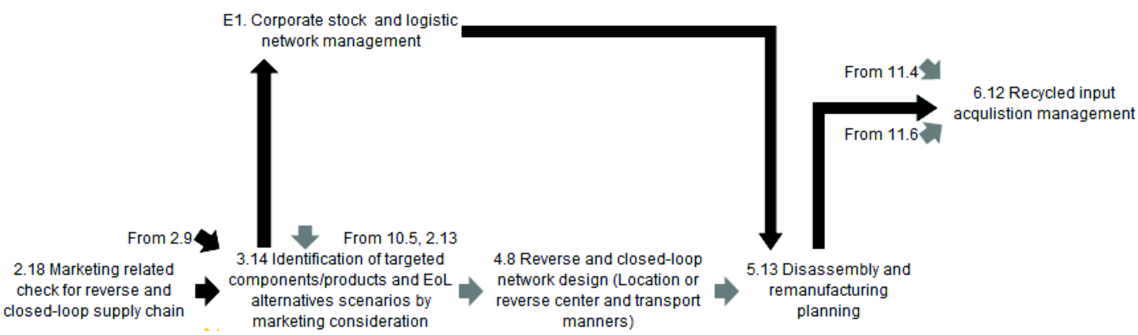


Figure 11-5: The actions chain relevant the scenario 1

Depending on the interaction, for preparing the action “disassembly and remanufacturing planning” (scenario 1), there are two previous parallel actions: "Corporate stock and logistic network management” and “Reverse and closed-loop network design and transport manners”. The difference between these two previous actions is that the first means the reversal logistics will be embedded into the normal network and the second one illustrate the construction of a new specific reversal logistic network for recycled/remanufactured materials. According to this difference, so there are two options registered as follow: Option 1 “embedded into normal network” and the option 2 “New particular reversal network”.

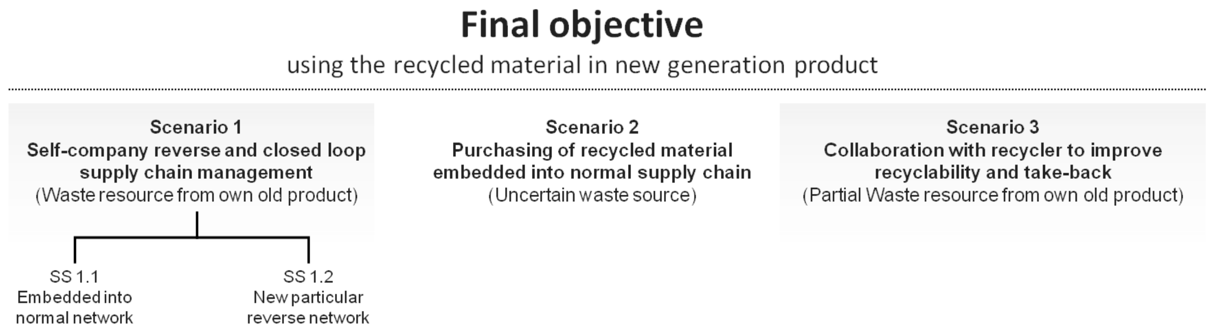


Figure 11-6: Two sub-scenarios of scenario 1 “self-company reverse and closed-loop supply chain management”

And then, exploration once again, these two actions have a same unique input, the action of “identification of targeted components/product and End of Life scenarios”. But in order to implement this action, there are three parallel groups of previous actions. The first previous group is “Formulation of improved remanufacturing process” proposed by the topic “design for remanufacturing”. Second previous group is the “selection or innovation of BAT (Best Available Technology or others)” which is brought by the topic “BAT of production” and the third group includes two independent actions: the “marketing related check for reversal and close-loop supply chain” and the “reusable check for product’s components”.

According to these correlations, the company might consider three sub-options to support the identification of targeted treating component. The first simple case is without any improvement and it only considers the actual re-manufacturability of the product by some marketing and technical concerns. The second option is to launch an auto-initiative improvement of product-design for making the remanufacturing friendly. And the third option focuses on the process of remanufacturing which requires either selecting the existing BATs, or innovate the new one.

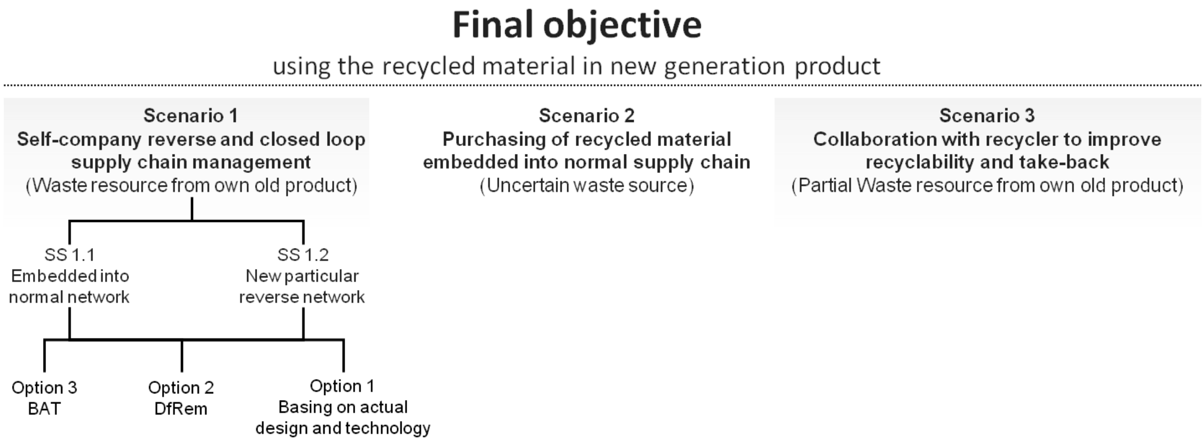


Figure 11-7: The scenarios map of Scenario 1 for “embedding recycled material”

Looking further for previous actions for option 1, there is nothing as inputs. So inversely, these two actions of first option (about marketing concerns and actual technical concerns) could be considered as two starting points of this simple branch. If the company owns a strong logistics network, it selects the sub-scenario 1.1 – embedding the reversal network into the normal supply-chain; this trajectory could be described as follow:

“Without any requirements of improvement, neither for product’s characteristics, nor for the remanufacturing process and tooling, the company auto-identifies the targeted remanufacturable components by considering the actual re-manufacturability (including the marketing and technical concerns). For these selected components, the company charges the whole remanufacturing process to embed the recycled material into the new product. And finally, the company does not create a new special reversal logistics network, the reversal material flow is embedded into the normal logistics network.”

Finally, after the same exploration of previous actions for all other branches, a systemic “applicable scenarios map” for final objective: using the recycled material in next general product has been constructed illustrated in the following figure.

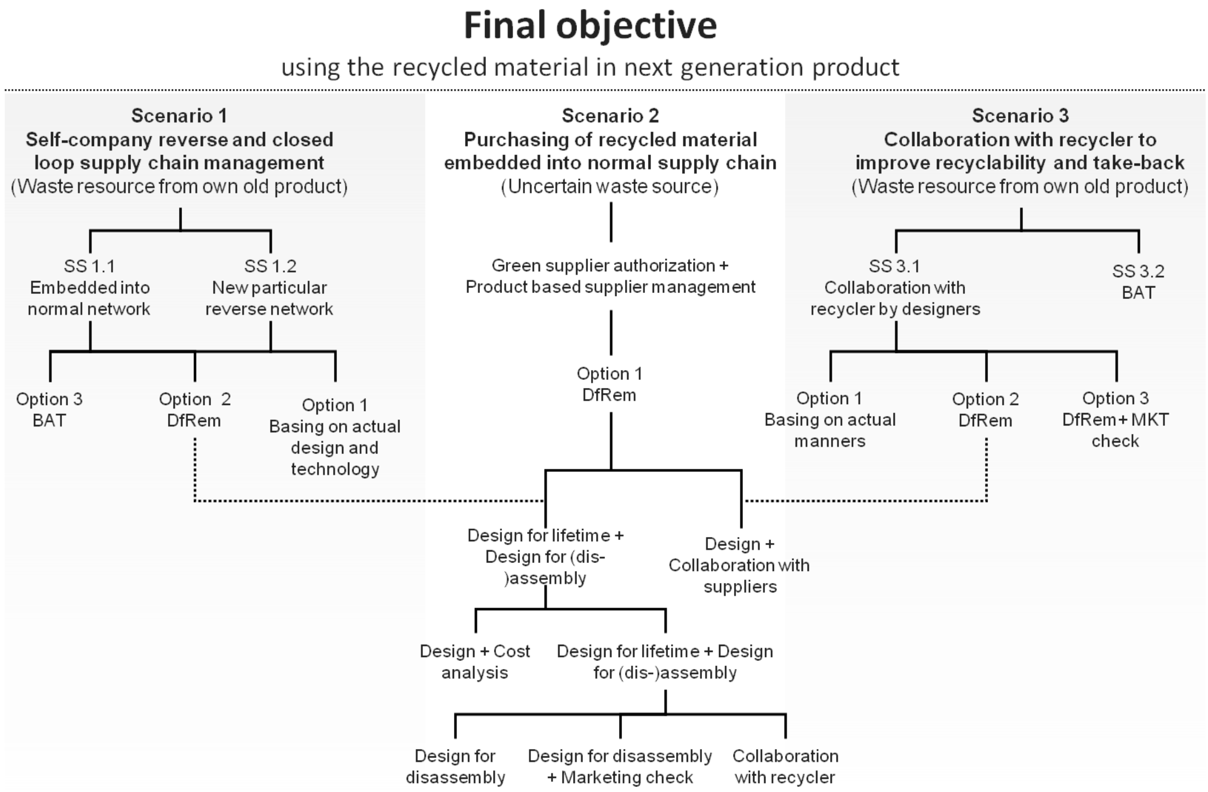


Figure 11-8: Scenarios map for "using the recycled material in next generation product"

The DfRem – "Design for remanufacturing" is a common element that might be required for each scenario (presented as two dotted lines). There are several different options also to implement this environmental topic. The designer could autonomously re-design the product's characteristics, or it could also collaborate with other reversal sources suppliers or material recyclers to improve the performance at project level, although this collaboration might be not considered as the right scenario at corporate level (if the company selects the "scenario 1" as the right one).

From the above figure 11-8, this "applicable scenarios map" summaries at least 47 different trajectories in order to resolve the objective of "using the recycled material in next generation product" (The "DfRem" contributes 5 trajectories for "scenario 2". With this contribution, the "scenario 1" proposes 14 different trajectories and "scenario 3" proposes 8). The above "scenario map" provides only the dashboard of the applicable trajectories. According to the data integrated into the cartography, there is a detailed achieving process for each trajectory with the definition of the inputs and the competence necessary, the action steps and the available tools. This detailed summary could directly support the company to identify a suitable trajectory according to its dynamic context and strategic objectives.

It's necessary to mentioned that the above "applicable scenarios map" provides several possible trajectories, and these trajectories are not strictly independent. It's means that the possibility of regrouping the different trajectories provides a great flexibility to plan a suitable corporate program. Depending on dynamic objectives and contexts, at first, the company could implement two branches in order to complete and optimize the final performance, such as the parallel implementation of the "BATs" and the "DfRem" could provide a holistic improvement of product's re-manufacturability. Secondly, the company might identify different trajectories for different applicable location (Ex: in Europe or Asia-Pacific), product's category (ex: core product, high-class product and accessories) or different steps of long-term program (ex: the first taking-back system is outsourced by a collecting service supplier, but finally, the company will set up its own remanufacturing network to treat about its waste product.)

11.3 Program implementation for certain corporate functions

Although this cartography and the proposed trajectories provide a systemic planning which includes the product and organizational topics, the companies might only require exploring the possibilities in a mini domain, either in product-oriented topics, or another organization-oriented. First reason is the frontier of responsibility which presents the user of this "Explorer" could not affect the global decision at corporate level, such as the manager of product design and development. So a "mini domain" is to proposed to fit this simplify requirement and limit the possibilities.

By considering the scenarios map generated in previous chapter, if the company requires only the possible trajectories which are constructed by some considerations from R&D department, the final "Scenarios map" is to be simplified by deleting the organization-oriented topics. The "scenario 1 - self-company reversal and closed-loop supply chain" which requires some organizational planning and process design, is totally out of the scope. The two other scenarios are applicable. But some topics, such as the development of BATs (Best Available Technologies) should be deleted (Figure 11-9).

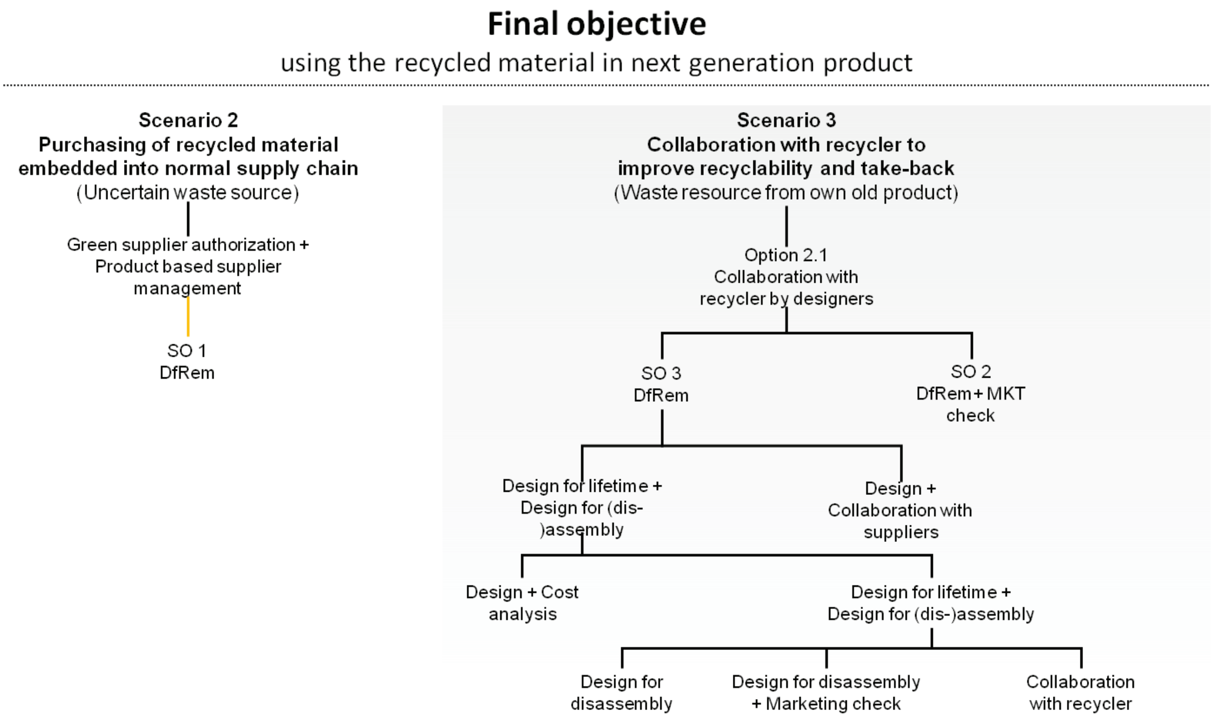


Figure 11-9: The "Scenarios Map" in mini domain for "embedding recycled material"

This generation results present that the "Design for remanufacturing" is not a mandatory element for considering the re-manufacturability in design phase. The "scenario 2 "illustrates a simple case is to only require the delivering of recycled material from the supplier and validating the final quality of inputs. And the "DfRem" only might contribute this option without any obligations.

11.4 Generation of trajectories with some specific conditions

In two previous scenes, the basic scene and the scene "mini domain", the weighting factor of all environmental topics/actions in cartography is equivalent. It means the user allows any trajectory to totally replace the others. But sometimes, the initial weighting factor of certain environment topics/actions is prioritized and these topics/actions have been selected. So the requirement of the trajectory exploration is modified as how to generate all possible trajectories to resolve the objective by the contribution of these pre-selected environmental topics/actions. This situation also appears once the user updates the existing program. And the implemented actions or topics are logically benefited to take easier the implementing of new program.

In order to answer this specific requirement, a new rule of exploration is necessary to be defined: If certain environmental topics or actions have been decided by the user, the other parallel actions or topics presents at same level, should be deleted.

By considering the "DEMO", if the company has decided to use the recycled material without any technical improvement, the "Scenarios map" will be simplified as figure 11-10.

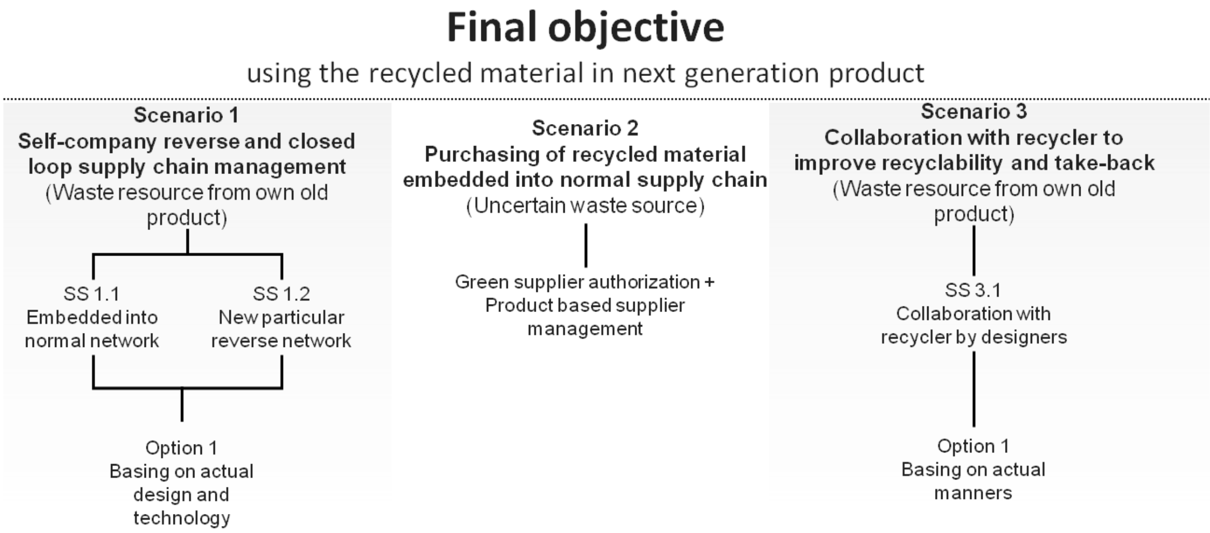


Figure 11-10: "Scenarios Map" without technical improvements for "embedding recycled material"

In this "Scenarios map", any topics concerned with the "DfRem" and "BATs" are deleted. The user (company) needs to only consider the marketing and financial impacts to decide the targeted remanufacturable components.

11.5 Scenarios map for Multi-objectives

In practice, the company needs to resolve parallel multi-environmental objectives at same time. Inversely, sometimes, an environmental objectives has required various parallel actions, such as the compliance of WEEE that asks the company calculating the recyclability rate of final product, financing or directly charging the take-back system for own waste product and providing an "end of life instruction" to present some recommendations for treating thus products. And if necessary, some technical improvement (DfRem or DfRecycle, for example) is further required to fulfill the law.

These two situations require an exploration from multiple starting points in cartography. So the mechanism for organizing this need is to be separated into two simple steps. At first, it independently generates all possible trajectories for each starting point. Secondly, it highlights the common trajectories (or certain actions/topics) to illustrate the sharability. The sharability means certain actions might answer multi-objectives. Once the user decides to implement these common actions for one objective, these highlights could directly remind the user that other objective might benefit these implemented actions to reduce the operational cost.

This “sharability” could be benefited also to update the corporate program. The “Simulator” (presented in next paragraph) registers the selected actions to implement. Once a new exploration find out a trajectory requires these actions, this trajectory might be highlighted to illustrate these implemented actions are profitable.

But, inversely, it’s necessary to mention that the common trajectory (or action) of multi-objectives does not mean that it’s a most simple and easiest solution for these parallel objectives in the meantime, because of sometimes, the common trajectory is not the most simple solution for all objectives. This equivalence (common trajectory = most simple or easiest) is true if and only if this common trajectory is necessary or decided for one of these objectives. A direct example comes from previous “DEMO”. The company needs to “use the recycled materials” and “provide the recyclability rate of product” in the meantime. Although the “DfRem” is listed as a common trajectory, it always exists a simpler trajectory “based on the actual technology”, as long as “DfRem” is not a necessary topic for improving the recyclability rate.

11.6 Co-product of implemented actions

The above scenes are based on the “tracking-back” mechanism in order to answer one or multiple fixed objectives. This mechanism starts from the last actions to reversely explore all previous actions (based on the “inputs”). But especially for some voluntary competition needs, the company doesn’t set up a clear predefined destination and it wants to maximum benefit the implemented environmental actions to generate some “co-products”. So in order to support this need, the “Explorer” needs to develop a reversal exploring mechanism which generates the trajectory by the “outputs” of certain implemented environmental actions.

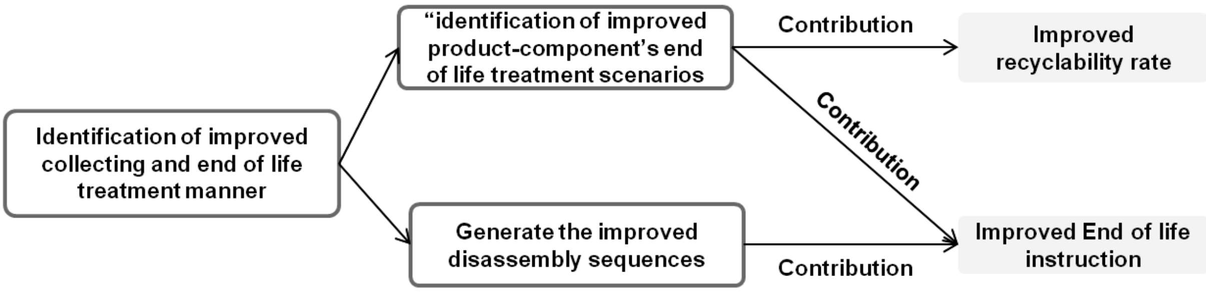


Figure 11-11: The co-products of "improved collection and end of life treatment manner"

From the previous "DEMO", if the company implemented the "use recycled material" by the collaboration with recycler, the "outputs" of the action "Identification of improved collecting and end of life treatment manner" presents three possibilities: the first and output supports the "identification of improved product-component's end of life treatment scenarios". This result might directly contribute to the calculation of improved recyclability rate. The second output transfers to "generate the improved disassembly sequences". And these two above "co-products" are required to generate an "end of life instruction". Finally, as a proposition, the company might generate or optimize the "end of life instruction" by benefiting the implemented action.

This chapter provides five scenes to generate the possible applicable trajectories based on diverse user's requirements. The "basic" and the "multi-objectives" scenes propose a most systemic view to treat about one or multiple pre-defined environmental objectives, including the product and organization-oriented topics. The scenes of "mini domain" and "specific condition" could be considered as two additional constraints to make the exploration. And these two constraints could be released at same times. The last scene "co-product" follows a reversal logic which generates the possible trajectory based on the implemented actions.

11.7 The detailed working flow to identify a suitable implementing trajectory

The previous chapters presented that various trajectories could be implemented in order to resolve an environmental objective. But because of the limit of corporate resources, the company needs to evaluate and prioritize among alternative trajectories, implement these priorities and follow up on their effects [Hallstedt S., et al, 2010]. So the difficulty is to identify a suitable solution according to the real corporate requirements and its context and finally to follow the progress status of all related activities. Generally, the "tactical" module supports department managers and experts in formulating an achievable roadmap to respond to strategic and project needs, step by step, running with the available resources. This roadmap gathers a chain of environmental methods and tools to pilot the generation of environmental improvements.

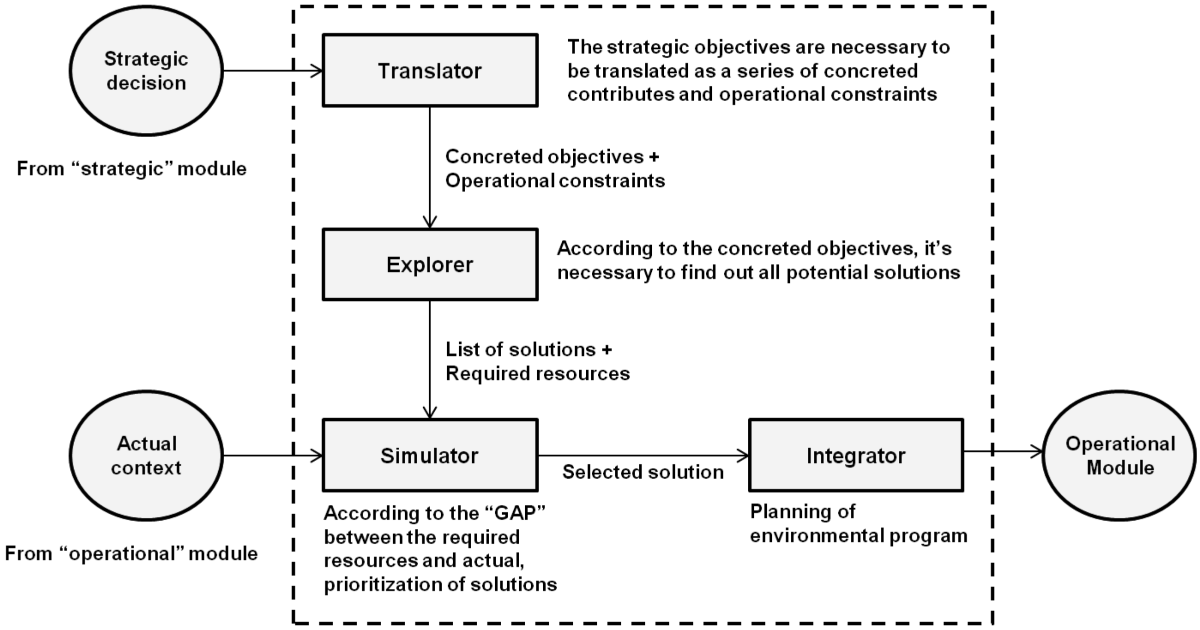


Figure 11-12: Framework and working flow to identify a suitable implementing trajectory

The figure 11-12 illustrates the general framework and the working flow to identify a suitable implementing trajectory. The strategic decision from “strategic module”, the systemic scenarios map of all potential trajectories and the actual corporate status are considered as three principal inputs to pilot the environmental program identification, the output of this “tactical” module. Globally, this process is constructed with four sub-modules: the “Translator” translates the strategic decision into a set of concreted environmental objectives and some additional operational preferences. The environmental objectives will be transferred to “Explorer” to guide the exploration of all potential trajectories and the required resources. According to these explored trajectories and the related summary of required resources the “operational preference” needs to be integrated into “Simulator” sub-module to pilot the prioritization. The “GAP” between the required resource and the actual one will affect also the condition of this priority. With the support of this prioritization, the company selects a comfortable solution and the “Integrator” integrate the required actions into the corporate daily work and organize some support activities (internal training and promotion for example) to launch the program.

11.7.1 "Translator"

Firstly, the strategic objectives are necessary to be translated as a series of targets which clarifies the executive environmental objectives and some operational constraints [Hallstedt S., et al, 2010]. Here, the operational constraints might include the consideration about the program cost, the duration or the final influence of these implemented programs, etc. This information about the constraints is very important to effect the solution's selection. [Hallstedt S. et al., 2010] and [Hedman J., Henningsson S., 2011] summarized five different scenarios of sustainable strategies: "Pre-compliance", "Compliance", "Beyond compliance", "Integrated strategy" to support the business development and purpose of new values. Even for a same environmental objective, the different strategic scenarios will lead to different solutions. Meanwhile, even for one strategic scenario, because of different situation, two companies might not make a same solution's selection. The simplest trajectory is not always the most suitable one. Answering to different needs, there are diverse corporate strategic requirements, either looking for the trajectory simpler or cheaper, or the trajectory that could create the leadership. The first company, for example, is a SME. The operational cost is a very critical condition for environmental program. So this company might like a "cheapest" solution which might mean that all required resources have been prepared and all disposable tools are with free license. But inversely, the second company needs to immediately answer the requirements from the laws, so it might prefer the "fastest" solution which needs to take a professional software or tool to accelerate the progressing of program.

Preference	Descriptions
Simple	The company focuses on the accessibility of the environmental solutions. The main criterion to select a suitable solution might include the actual situation of required knowledge (maximum knowledge has been obtained) or the required actions that are simply to be released.
Cost	The company focuses on the operational cost of environmental solutions. The main criterion to select a suitable solution might include the required training fee, the cost to collect the environmental data or the cost to integrate the environmental knowledge, etc.
Speed	The company focused on if it could answer the requirement as fast as possible. Especially, this preference is to answer some emergent needs or legal requirements
Path dependence	The preference describes that the company want to follow the existing solutions of its competitors. The experiences of all implemented solution could potentially reduce the operational risks
Explorer	Instead of above "path dependence", this preference aims to create the new solutions that are different with the main competitors. This difference might create the competitive advantages for business development.

Competence	The company focuses on the development of key competences during the implementation of environmental solutions. It means that the company prefers the solution might bring the key competences into the company. The description of thus competences might be predefined by strategic module.

Table 11-1: Example of the "operational preferences"

So in order to resolve this difference, the "tactical" module provides a "Translator" sub-module to translate the strategic decision into a list of potential environmental objectives and to clarify the operational constraints. The environmental objectives will be used to explore the potential solutions and the "operational constraints", which will be named as "operational preferences", and integrated into the judging mechanism to identify a suitable solution. A first list of "operational preferences" has been proposed in table 11-1.

11.7.2 "Explorer"

The principal mission of "Explorer" sub-module is to explore all potential trajectories to answer the fixed environmental objectives in "Translator". The above sections (presented by a demo) indicated the mechanism of exploration according to different requirements. Meanwhile, it's also necessary to summarize the list of required resources (material resources and immaterial resources) for each trajectory to support the next priorization.

10.7.3 "Simulator"

As the result of "explore", a summary about operational characteristics of each potential trajectory has been proposed. This summary will list the evaluation results about their required actions, the necessary cost and time frame, the competences and resources should be planned and the list of intermediate and final deliverables.

Based on these summaries and according to the corporate "operational preferences", the "Simulator" needs to make the order of all explored trajectories. Once the company validates the priori solution and selects a comfortable one which defines the objective achieving process, step by step, with a series of selected methods, this result will be transferred to "Integrator" to launch the program.

But the "necessities" of each trajectory is dynamic based on the corporate objectives and its dynamic context. This dynamic is depended on the existence of necessary resources and the different manner to use these resources. So beside of some mandatory necessities (the necessary software requires the license fee and some time cost presented as the duration for implementing the whole trajectory, for example), the lack of certain resources leads to some additional actions which is required for making the resources available, such as the development or recruitment of competence or the establishment of data exchanging channel. Completion of these two necessities generates a final result on implementable status for each potential solution.

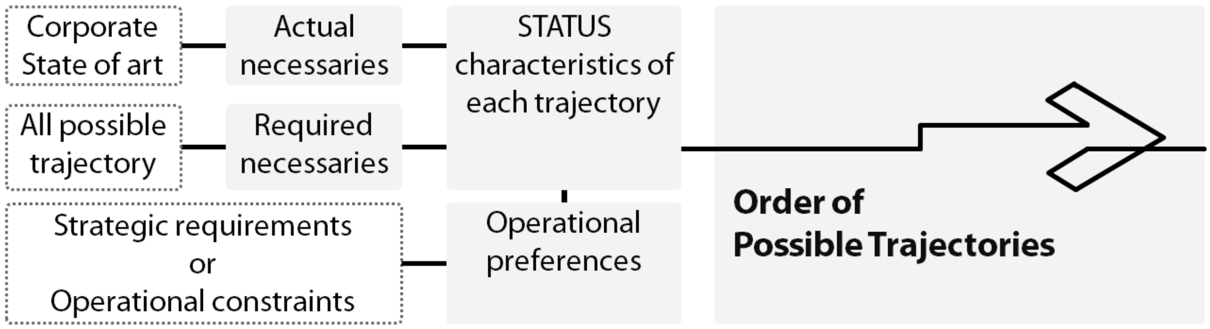


Figure 11-13: General process of "Simulator"

This diversity of strategic requirements leads to the operational "preferences" that could not be considered as a unique criterion for selecting the suitable solution. A detailed report about the necessities of all trajectories is also necessary to be considered. So the mechanism of "Simulator" is designed by two steps: 1) Step "Necessities". This step is defined to identify the "gaps" between all required resources and the related corporate answers for all potential solutions. This difference is used also to measure the additional operational cost, and further for establishing a completed summary of all necessities; 2) secondly, step "prioritization", according to the completed summary, this step is defined to make the order of all explored solutions by considering the corporate "operational preferences" which is translated from the "Translator" module.

Step 1: Necessities

As mentioned earlier, the operational status of each trajectory is dynamic. In order to describe them, the final structure of the operational necessities includes two types of information: the "static requirements" and the "dynamic requirements".

The "static requirements" describes the mandatory operational characteristics of each trajectory which have been summarized in "explorer" module. These characteristics include the chain of required actions to release this trajectory and the necessary competences and resources for each action etc. Because of these operational characteristics of each trajectory are summarized directly from the requirements of environmental methods or tools (the information registered into the environmental database of "explorer" module), the list of the "static requirements" is same for all companies. For example, a detailed environmental nomenclature of product is obligatory to launch a life cycle analysis with the quantitative software. In order to prepare this nomenclature, the competence and the resources which ensure the data collection, normalization and analysis is required for all companies that want to release this action.

Meanwhile, different potential trajectory requires different operational characteristics. Especially, for answering a same objective, the difference of operational requirements provides various possibilities to select a suitable one based on the corporate context. So facing the explored trajectories, the "necessities" sub-module firstly summarizes all required operational characteristics for each trajectory that will be used for next "match process".

Secondly, facing these operational requirements of each trajectory, it's necessary to make a "resource matching process" to evaluate if these requirements have been presented into company. Meanwhile, the lack of certain resources leads to the additional cost to complete them. For example, a company misses the knowledge about LCA software. In order to make a quantitative LCA by software, this trajectory requires some additional actions, such as the purchasing of software license and the organization of internal training. But the different corporate context leads to the dynamic of the list of all additional actions and cost. And these actions modify the complexity to implement thus potential trajectory. So this type of additional requirements is named as "dynamic requirements" which should be added into the summary of the necessities of each potential trajectory for each company.

Finally, the matching results of the "static requirements" and the additional "dynamic requirements" will be summarized together to describe the whole operational requirements of each potential trajectory into this company. And furthermore, the company could consider this summary and the "operational preferences" to select a suitable trajectory for answering the concrete environmental objective.

Step 2: Prioritization

In previous step, a final summary of "static and dynamic requirements" indicated whole operational necessities of each potential trajectory. According to the corporate needs, which have been translated by the "operational preferences" in "translator" module, this step makes the prioritization of all potential trajectories and proposes the suitable one. In this step, the requirement of "operational preferences" is the principal consideration which will be translated as a set of criteria constructed by the static and dynamic requirements.

The different evaluation methods to analyze the priority of these trajectories lead to different results. Here, it's very difficult to provide the absolute criteria. But the summary of "necessities" of each trajectory could provide some reference of criteria to support the decision. According to the propositions of some operational "preferences", the next table 11-2 summaries some related referential criteria to make the order of potential trajectories. The first two columns list the five "preferences" proposed in "translator" module. They are regrouped into three strategic categories. The third column shows some proposed criteria for making the order of trajectories. The company might select one or all criteria to make a final decision. If the multiple criteria have been selected, a two-dimension matrix could be used to globally summarize the order with each criterion.

Vertical dimension of matrix lists the possible trajectories; and the horizontals dimension lists these four selective criteria. The cellules of this matrix summarize the order of trajectory by each criterion. And this summary could provide a global view to support the final decision.

DEFENSIVE	Preference "Simple"	In this "Simulator", the "Simple" might be evaluated by the minimum action numbers with minimum or the simplest necessities. The most common trajectory for multiple objectives and the most benefits from the implemented actions might be also considered
	Preference "Cost"	The cheapest trajectory or the most benefits from the implemented actions
	Preference "Speed"	The fastest trajectory or the most benefits from the implemented actions
COMPLIANT	Preference "Path dependence"	The trajectory has been successfully done by the company it-self or others.
BEYOND	Preference "Competence"	The trajectory develops the key competence pre-identified or maximum necessities required
	Preference "Explorer"	The new trajectory that is not same with competitors

Table 11-2: The "preferences" and referential criteria of selection

The preference "Simple" requires a trajectory straight and simple. The "straight" here is translated as it prefers a trajectory with the minimum environmental actions numbers to answer a fixed objective. And the "Simple" here is defined as the minimum necessities numbers, maximum the achievement of required necessities or the Maximum required actions have been done by the previous corporate program. The common trajectory for answering multiple objectives is also necessary to be considered.

The preference "Cost" requires a trajectory as cheap as possible. The critical criterion is the total necessary cost required by the summary of static and dynamic actions. The maximum matching of required necessities and the number of implemented actions with simple necessities could be considered also as two additional criteria to ensure the "cost" of the trajectory.

Similarly, the preference "Speed" requires a trajectory as faster as possible. The critical criterion is the total duration code by the sum of actions. The maximum matching of required necessities and the number of implemented actions with the shortest timeframe could be considered also as two additional criteria to ensure the "speed" of trajectory.

The preference "Path dependence" requires resolving the environmental objective by following the existing trajectory which has been implemented by company it-self or other competitors. In order to make order by this preference, it's necessary to make an industrial analysis and formulate a referential trajectory. And finally, it's looking for a trajectory with the minimum differences with this reference.

In this step, the requirements of preference "competence" are translated as a trajectory which could provide maximum competences and possibilities for future improvement. The company might pre-identify a list of key competences, and prioritize the trajectory according to the number of production. Certainly, without the definition of the key competence, this preference might be considered as the production of the maximum possibilities to release coming improvement. So the maximum number of required necessities seems a referential criterion to make the priority.

The last preference "explorer" describes a corporate need to become the first achiever for certain environmental topics. This preference requires the maximum differences with the implemented trajectories.

Certainly, the company could define also some self-criteria to make the priority. Once the company decides and validates the order, the first prioritized trajectory is automatically selected as a suitable trajectory to be implemented. The related environmental actions will be also registered as the implemented actions which directly modify corporate conditions for next exploration in future.

11.7.4 "Integrator"

Once the trajectory has been selected, it's necessary to define an "operational programming" procedures for planning all related actions or steps and organize the necessary resources. This

"Integrator" is defined to develop the operational controls and create the organizational support for ensuring that those objectives are fulfilled.

The output of "Simulator" module summarized a standard working flow to resolve the environmental objective. This working flow is not related with real corporate situation which defines the collaboration flow and corporate working process. According to the corporate definition of each function, a required environmental action might be totally charged by a function or might be collaborated by several functions. So firstly, in order to integrate the required actions plan, it's necessary to designate the related responsibilities of each corporate function to contribute the environmental integration.

Step 1: Clarify the responsibilities of each proposed action

The "simulator" provides a set of environmental actions which require a list of working targets need to be done. According to the existing responsibilities of corporate functions, the "integrator" suggested to clarify the corporate function or person who is responsible for achieving the targets of each proposed action. A corporate function might charge multiple actions and inversely, a proposed action might require the collaboration of multiple functions. In order to ensure the achievement of such targets, it's necessary to identify the timetable, the budget support and the indicators to measure the performance for each responsibility. The outline for such definition might include:

- The objective of proposed action
- The Targets for ensuring the achievement of action
- The responsible function or persons for each target
- The financial support/budget
- The timetables (Deadline of action, the actual completion, etc.)
- The support need about related methods/tools
- The indicators to measure the performance

Step 2: Review and create new process to ensure the achievement

According to the definition of precedent step, it's necessary to create a new process to connect the works of each corporate function. This connection need to consider the interface of environmental data or decision between different related functions and the manner to integrate the required interactions into the existing process. The outline of this step is used by next "operational module" to update the related corporate tools which could ensure the efficiency of collaboration.

Step 3: Building organizational support

Achieving success in implementing environmental actions for each objective depends upon making sure that each relevant worker has received adequate training. So develop a training program and internal promotion plan that ensure everyone understands both the objective and their role in ensuring that they are followed. In order to prepare the training program, the following elements might be mentioned:

- The environmental issue is a new thing for industry. In order to achieve the environmental objective, it's necessary to take related some "know-how" and competences. So according to the outline of step 1 of this "integrator", this technical training need to be defined to provides the excuses and the lessons about the required methods, tools, technical knowledge of redesign or operational control , the procedures to implement the actions and some other related knowledge.
- Some authors mentioned in the "Part II" proposed also the training about the global context and all potential profits of environmental integration in order to encourage the related stakeholders. This content might include:
  a. The stern reality of environmental pollution and the macro tendency of environmental protection
  b. Legal requirements and competitors' activities
  c. The corporate strategy of environmental integration and all potential profits and awards.
  d. The presentation about implementing programs and the responsibilities of each related function
- The relevant persons: All contents of training materials need to be arranged and organized for different trainees. For management level, the emphasis might be the profits of corporate development, the budget necessary, the timetable and the required human resources, etc. But for operational workers, the training contents might focus on the details of methods, tools and technical knowledge.
- How to train: The training manner, such as the lessons, the exercises of relates tools and methods, the internal media and seminars; need to be considered to ensure the efficiency of environmental training and promotion.

Once these contents have been clarified and defined, these details will be transferred to "operational module" to optimize the interaction manner basing of federation of engineering tools.

11.8 Discussion about the scenarios map of environmental trajectories

The basic database for generating the environmental trajectory is a holistic environmental cartography. Each environmental action is considered as an independent operational unit which is driven by inputs and generates a set of outputs. And these outputs might drive several following actions which are proposed by different existing methods or practices. This type of multi-interactions ensures the possibilities to achieve an objective by several different ways. So based on this "cartography" constructed in chapter 10, especially, by considering the interactions between different environmental actions, this chapter is to present a "tracking back" mechanism to generate the possible operational trajectories (a chain of environmental actions) to answer the needs of environmental objectives. Because of the limit of corporate resources, the company needs to evaluate and prioritize among alternative trajectories, implement these priorities and follow up on their effects. Then, a detailed working process to identify the suitable trajectory has been proposed. This working process considers the strategic preferences and the dynamic corporate context into the prioritization of all potential trajectories. Finally, according to the selected trajectory, a roadmap which is running with the available resources, gathers a chain of environmental methods and tools proposed to pilot the generation of environmental improvements.

11.8.1 A vast number of environmental actions ensure a systemic proposition

The problematic demonstrated that a systemic collaboration between the product-oriented and site-oriented approaches could support the company to make a suitable identification of environmental programs.

Firstly, the scenarios map of all potential trajectories is proposed depending on the environmental cartography which has involved 122 typical environmental actions from an in-depth analysis of existing methods and practices of 20 topics for organization-oriented approach and 26 for product-oriented approach. This vast number of analyzed methods ensures a complete intelligence support for generating the trajectories. Meanwhile, in this environmental cartography, the existing methods and practices have been broken down as a series of environmental actions. The linkage between these actions is no longer dependent on the perimeter of the methods, but depends on the flow of information between them. As long as a first action can provide all the needs of post-one, they can be linked together as a chain of actions. So without the label of the method proposed, the environmental action is considered as an independent applicable unit of the whole network. This type of "interaction" breaks down the perimeter of product-oriented and site-oriented approaches, and it will pick out the necessary applicable units (actions) to re-construct an operational trajectory to resolve the environmental objectives.

Secondly, in the whole environmental cartography, the actions are linked by the "interactions" which are defined by the informational flows among them. Sometimes, if necessary, the environmental data should continuously flow between the actions proposed by two approaches. During the process for contacting the supplier to import the recycled materials, for example, the design team need to access the whole process in different way at different times in order to set up the specification, validate the final quality or improve the characteristics of product according to the new input from suppliers. The Scenarios map and the proposed trajectories doesn't only standardize the actions chain and their order and timetable, they also define how the environmental data and decisions exchange between these actions, especially, between two product and site-oriented approaches.

11.8.2 Dynamic proposition according to different exploration conditions

Thanks to the environmental cartography, especially, the definition of the "interactions" between different actions, the "tracking back" mechanism could explore vast number of operational trajectories in order to resolve the environmental objectives. As mentioned in previous paragraph "Demo of exploration", in order to integrate the recycled material in next generation of product, 47 different operational trajectories have been proposed. And each trajectory is considered as an independent trajectory which could completely replace others. Because different operational trajectories require different chain of environmental actions, the operational difficulties and necessities (such as the required cost and time frame, the necessary competences) vary from one to another. Meanwhile, the environmental cartography summarized the actions in two approaches, the product-oriented and site-oriented approaches. The implementation of these actions concerns the activities of several corporate functions. The differences about the required action group also cause to the different related function and the manner of collaboration among them. The company could select one or more suitable trajectories to resolve environmental objectives according to its practical individual status and the need of corporate development.

The above generation of operational trajectory is in a liberal environment. It means that each environmental action is independent and equivalent for company. And the company doesn't set up any preferences to make the generation. But practically, in order to simplify the potential trajectories and improve the efficiency of selection, the company would like to set up some specific conditions to hide some unnecessary trajectories. In this chapter, four types of specific conditions have been presented to illustrate how the “tracking back” mechanism modifies and simplifies the actions’ chain, and further proposes a simplified operational scenarios map.

Firstly, it presented the reduction of applicable scope, the company implements the environmental actions either in product-oriented approach, or in site-oriented approach. This situation normally appears when the user doesn’t stand at the whole company level. The user just explores the trajectory only for one corporate function, such as if the product-design team want to integrate the eco-design into the R&D process, and it has less power or interest to affect the activities of other functions. When the company considers the environmental actions in only one of these two approaches, the “tracking back” mechanism will delete the action involved in another approaches, thereby deletes the trajectories which contain these relevant actions, and finally simplify the final scenarios map.

Secondly, this chapter presented the generation of trajectories within some corporate pre-preferences of environmental actions. Based on the consideration of some specific requirements, such as the answering of environmental laws or following the industrial common requirements, the company requires that the generated trajectories should contain certain mandatory actions. And other trajectories which don’t pass these actions will be deleted. Meanwhile, the requirements about certain competences and technologies, and the consideration about operational cost and executive ability also lead to these pre-preferences. In order to integrate the recycled materials, the company pre-defined, for example, the recycled material will be imported by the material suppliers. So in scenarios map, some other trajectories will be deleted which require the company to charge the whole recycling process or collaboration with recyclers to take back the materials.

Thirdly, it presented, in paragraph 11.5, how to find out a common trajectory to treat multi-objectives. The common actions will be highlighted and this common trajectory could optimize the sharability of environmental actions, reduce the number of required actions and operational resources, and thereby encourage the environmental integration into the company.

The above exploration is to find out the potential trajectories to answer one or more concrete environmental objective. But the paragraph 11.6 presented an inverse status. It illustrated how the “tracking back” mechanism and the environmental cartography support the definition of environmental objectives depending on the actual corporate achievement. The basic logic is to profit all multi-outputs of certain actions to fulfill other environmental objectives in a quicker way.

11.8.3 Distributive registration of operational necessities

The integration of environmental issues requires finding out a systemic operational trajectory, it also need a clear plan to organize the details about the timetable of each action, the responsibilities and working manner of each action and related corporate functions, and the working flow among different environmental actions.

Facing this type of requirement, the trajectory doesn't only provide the macro solutions to treat the environmental objectives for global planner of environmental programs; it also breaks down the whole trajectory into a series of implementable actions, thereby it thus dispersed the all operational necessities inside each node (means "action") of trajectory, such as the responsibilities, the treated information and the required competences. Each node only focuses on its necessities. And all data of whole trajectory have been distributively stored in each action. The relevant corporate departments of each action can only clearly understand the working details of this action and the interface with others. It's not necessary to consider the details of other actions. Meanwhile, the outputs of each action can be considered as a series of deliverable documents which register the targeted environmental results of this action. Such decentralized structure of data registration ensures the clarification of the responsibilities and working performance of each action and each corporate function. It further ensures an efficient training and internal communication which delivers the adequate information to each relevant person.

Secondly, the outputs of each action don't only contain the environmental data or results, they also include the knowledge to collect and generate these data. Each output stocks the intangible knowledge into the tangible document. For implementing again this action in future, the decentralized stocked knowledge could be easily and targeted prepared and analyzed. And it enhances the capacity of existing knowledge inheritance.

11.8.4 Redundancy of trajectory ensures the robustness of key necessities

The whole scenario map provides several trajectories for each concrete environmental objective. And each trajectory is independent and it can completely resolve the objective. Once the company makes a selection according to its particular context, only one trajectory has been picked out. So inversely, for this environmental objective, there are also a number of possible alternatives. So facing the urgent case, during the implementation process, when the selected trajectory cannot continuously be executed a cause of the change of corporate status, such as the key competence lost, the new cost down strategy, etc., this redundant design can quickly perform a variety of other possible backups to fulfill the final objective. Meanwhile, some executed actions will be considered as the new corporate status. By considering this operational environment's update, a most compatible trajectory will be proposed. So the multiple possible data connection pipes (the interactions among different actions) and multiple contributions of trajectory enhance the robustness about the fault-tolerant ability of key resources.

11.8.5 Systemic programming for multi-objectives

Practically, the multiple objectives appear at the same time. As mentioned earlier, in paragraph 11.5, this "tracking back" mechanism explained how to find out a common trajectory to treat multi-objectives. This common trajectory could maximum ensure the sharability of environmental actions and reduce the necessity of operational resources. In the scenarios map of each group of multi-objectives, there is a systemic route map about the organization of all relevant actions. At micro level, it also clearly explains the targeted environmental objectives supported by each action, as well as during the process of execution, the working sequence and the collaborative relationship. This systemic view might support the program planner to design a comfortable working flow. And it supports also the clarification of the responsibilities of each action and each relevant corporate function in the context of multi-objective.

11.8.6 Dynamic prioritization depending on different strategic preferences and corporate context

Today, facing the vast number of environmental methods and tools, there is not an absolute suitable trajectory to answer an environmental objective into all types of companies. So the selection of the suitable trajectory should consider the real situation of each company. Firstly, even for the same objective, the different strategic preferences will lead to different selection. The trajectory, which brings the most market influence, might not answer the needs about the simplification. Beside the classic analysis about the purpose of environmental tools and methods, in this thesis, the proposed mechanism to identify the prioritization involves the multiple criteria to evaluate the operational results. These criteria consider several aspects, such as the time, the economic aspects, the final influence and the operational complexity/risks. These multiple criteria provide several additional references to consider the selection of suitable trajectory. Meanwhile, the analysis about the operational complexity doesn't only focus on the necessities of each trajectory, but it also embeds this analysis in line with the corporate context. The absolute analysis of the necessities between two environmental methods might bring a first result about the operational complexity. But the implemented environmental program and actual knowledge situation might affect also this result. On the other side, the lack of required data and competence will lead thus trajectory more complex to be implemented. This proposed mechanism to identify the suitable trajectory involves this dynamics into the decision. A new dynamic indicator of the priority is defined as the "Gap" between the corporate situation and the necessities of each trajectory. This dynamic "Gap" will be added into the multiple criteria to consider the final selection of suitable trajectory.

11.8.7 The possibility of customer setting

The generation of operational trajectories is depending on the definition of the "interactions" in the environmental cartography. And the "interactions" are defined according to the proposition of existing environmental methods and practices. So these definitions are open to be modified and updated. Today, there are many environmental tools being developed. Especially, during the process of execution, the company might find out some other new "interactions" among the executed actions. These new discovers could complete and update the environmental cartography and they ensure the generation of more new trajectories.

11.9 Conclusion

Depending on the cartography of environmental actions, this chapter presents a "tracking back" mechanism to support the company to pick out the right environmental actions which will re-construct several operational trajectories. Each trajectory is considered as an independent solution to resolve the corporate objectives. According to this exploration, a detailed working process is proposed to classify the solutions depending on the dynamic corporate preferences and context. Finally, the selected suitable trajectory will be integrated into the company to pilot the environmental improvement. Additionally, there are several specific conditions, such as the mini domain of action's exploration, the selection with the preferred actions and the exploration for co-product, that have been also proposed to optimize the exploration results.

Depending on an in-depth analysis of environmental methods, the proposed trajectory could provide a systemic proposition which harmonize the product and site-oriented approach at "action" level. The Scenarios map and the proposed trajectories doesn't only standardize the actions chain and their order and timetable, they also define how the environmental data and decisions exchange between these actions, especially, between two approaches. Meanwhile, the multi-proposition of potential trajectories allows the company to select the most suitable operational trajectory according to its particular context. And the multi-objectives combination supports the program planner to design a comfortable working flow. And it supports also the clarification of the responsibilities of each action and each relevant corporate function in the context of multi-objective.

Finally, the redundancy of the trajectories ensures the robustness of the lack of principal necessities and the final fulfillment and the possibilities of customer setting ensure the update and continuous improvement of the operational trajectories in the future.

V

THE CARTOGRAPHY IN USE

This experimental protocol aims to define the sequence of experiments that will enrich knowledge in the practice of environmental integration and get the demonstration of the validity of the scientific propositions. Firstly, based on the environmental cartography and the “tracking back” mechanism, a serious game, named “SimGreen”, was created to validate if above propositions might support the systemic environmental integration. This serious game was firstly organized for academic lessons of French engineering school to validate the concept of dynamic definition of the environmental trajectories for an environmental objective. Meanwhile, this game was animated with several environmental experts from IFTH (French Textile and Apparel Institute) and the G-SCOP laboratory to further justify the pertinence of the proposition. Secondly, in order to ensure the robustness of the “Tactic module”, experiments were organized in two companies: 1) Quiksilver: it is one of the world’s leading outdoor sports lifestyle companies and 2) Festilight: it’s a SME (small or medium-size enterprise) for decorative and festive lighting service.

The feedbacks demonstrate that the “Tactic module” successfully provides a systemic and depth support to ensure the achievement of pre-defined environmental objectives. The multiple “scenarios map” provides a large systemic view of potential solutions. By integrating the multiple “prefers” of selection, the company might efficiently identify a suitable group of trajectories according to real needs and their context. The pre-formulated action chain and the list of available tools support the company to identify the real operational process and organize the working flow among different corporate functions (for large groups) or workers (for SMEs).

Chapter 12 - Experiment N°1: A serious game to contribute to the comprehension of the efficiency of systemic integration

The purpose of the environmental cartography and the “tracking back” mechanism is to provide the company with a systemic intelligent support for augmenting the efficiency of environmental integration. The basic hypothesis is that a systemic view of the potential scenarios can ensure the generation of a right solution to treat environmental problems. Especially, this benefit appears when multiple environmental objectives need to be treated.

So in order to validate the efficiency of this systemic integration and to contribute to the environmental training of such systemic consideration, the first experiment is based on the development of a serious game. This serious game, named “SimGreen” is based on the structure and expertise of the environmental cartography and “tracking back” mechanism. The principle purpose of this game is to push the player to identify a suitable trajectory by considering multiple dynamic objectives and the limit of operational resources.

12.1 What is a serious game?

According to [Yusoff A., 2010], a serious game is defined as “a learning tool that incorporates game technology for the purpose of achieving learning objectives rather than pure entertainment”. There are some similar terms such as “simulation game”, “game based learning”, “education game” and “edutainment” [Wouters P. et al., 2007] [Pourabdollahian B. et al., 2012].

Learning and education via the game is the main objective. In order to provide a high level of education, [Yusoff A., 2010] summarized three perspectives for designing a serious game: the “educational perspective”, the “Psychology” perspective and the last “computer science” perspective. These next two subsections will illustrate some considerations about the game design within the educational perspective and Psychology perspective.

12.1.1 Educational perspective

[Yusoff A., 2010] presented that “the effective learning is measured by how well the learner understands or performs according to what has been taught”. So the key of the successful pedagogy is to find out a right method and apply it when the studying. This method should support the knowledge transfer and the creation of a great relationship between the teacher and learner. Firstly, the contents of the serious game should be carefully designed according to the nature of serious topics. [Gilbert, L. and Gale, V., 2008] summarized four different types of serious contents to be taught: the facts, the procedures, the concepts and the principals. For each type, several characteristics are required to be highlighted. For teaching the facts, a series of standard characteristics should be used to illustrate it, such as the date and the related participants for a historic event. For procedures, the phases of the observation and synthesis about the important issues of each step are two key elements. Thirdly, the education of the new concept could be considered as a learning of the new values or ideas. So an introduction is necessary about the environment and context when a new idea is generated. The logics and the tendencies behind of idea are key elements to be presented. Finally, the learning about the principles is based on the relationship between the causes and the effects. This new principle proposes a set of guidelines, rules or recommendations to predicate and implement some issues.

Meanwhile, some literatures illustrated several pedagogical theories to optimize the learning design. [Paraskeva F. et al., 2010] presented that repeated reinforcement of the key activities of serious topics is necessary to encourage the learner to match the correct direction. Additional, [Yusoff A., 2010] summarized that the game rules need to allow the learner to obtain knowledge by his own actions; allow the learner to collaborate and negotiate in acquiring new knowledge when they learns with other colleagues.

Finally, it’s necessary to notice that the different capacities of learners directly affect the effectiveness of the serious game. These capacities include the knowledge background, the recognition and comprehension of new things, the competence about the analysis, synthesis and finally the competence to apply the new knowledge into the new situation. So a clear definition of the targeted learner is a key element that should be treated and focused on before the game design.

12.1.2 Psychology perspective

According to the definition of [Yusoff A., 2010], this psychology perspective focuses on the attraction of the serious game. In fact, there are two inverse points to be treated: removing the negative emotions and encourage the positive values thus contribute the success of the game. Additionally, [Yusoff A., 2010] summarized several issues that should be highlighted.

Firstly, the win's knacks of the serious game could not be designed too difficult to be found. The learners, specially, the academic students, are not neither the master of the game, nor the serious contents. Sometimes the game fails, because of a lack of a good design of win's knacks. This bad design results in learner "losing heavily, becoming frustrated, remaining ignorant of what went wrong, unsure how to play or learn, finally this leads them giving up on the whole game" [Yusoff A., 2010].

Secondly, the funny is important. But the funny is not a unique element of the serious game. The game design should ensure the learner could find out the serious topics and receive the related abilities or knowledge. [Yusoff A., 2010] presented that "when the students were fully immersed in the game, they sometime ignored certain aspects of the play (or certain learning activities), skipped the feedback, and failed to interact with the game directions."

Thirdly, the game design needs to demonstrate the received knowledge and skills are meaningful or usable. With the running of the game, a great design of game rules allows the learner to gain a win for part of challenges in next level or step by using these new abilities and knowledge. This sense of achievement could encourage the learner to continuously play this game.

Fourthly, [Yusoff A., 2010] indicated that today, in the current world, because of the existing of so many different options, it's difficult to judge what is right or wrong, especially, when we teach the new concepts and principles. The scientific hypothesis and the limits of research sometime generate the disagreement. So the out comings of the game are not an arbitrary imposition of this predefined contents, it's necessary to provide some proofs to measure how well they are doing something right.

12.1.3 Conclusion of key points to design a serious game

Finally, to resume, the design of serious game needs to consider these following points:

- The educational objective should be considered as a key element of the serious game. During the preparatory phase, the game design need to clarify the purpose and the main objectives, such as the targeted contents which need to be educated, discussed and summarized by the learner and the new knowledge about some new conceptions.
- The activities and the processing design need to make the learner feel more motivated and interested into the targeted contents.
- It's necessary to create the positive relationship between the playing success and the targeted contents or knowledge. Firstly, the targeted contents and knowledge should be

easier found out. Sometimes, the game might be designed to generate some playing fails due to the lack of targeted contents or knowledge. But in next step, the learner might immediately resolve these fails by using the obtained new knowledge.

- During the play, the game doesn't judge if each decision is correct or wrong. Ideally, the game rules encourage the learner to find out the advantage and make a judgment by themselves.
- The final achievement need to be measureable to judge if the serious game achieves all predefined objectives.

12.2 Serious Game design

According to these 5 key points, a serious game, which is named "SimGreen", has been developed. The "SimGreen", similar with the famous video game "SimCity" and "The Sims", means that this is a simulative game which provides a virtual context to learner to plan a series of environmental activities.

The purposes of this serious game include two main objectives: Firstly, in order to validate if the proposed cartography and the "tacking back" mechanism could provide a systemic view about the environmental related activities and if this systemic view can improve the efficiency of environmental program's decision. Secondly, by playing this game, it presents a new conception to learner that "**At the beginning of planning stage, a systemic view of the potential trajectories and states of required resources could optimize the decisional process about the integration of the environmental activities**". According to the proposals described into previous chapters, some systemic considerations need to be represented into the game:

- Firstly, do the actual competences and implemented actions could contribute to the new needs?
- Secondly, in order to answer an environmental objective, how to decide the most suitable trajectory from all possibilities? And which indicator might be considered to make the decision?
- Thirdly, is there an optimized trajectory that could be implemented to answer multiple environmental objectives?

Meanwhile, the selection of suitable trajectories depends on the dynamic context which includes several operational constraints, such as the obtained knowledge, the availability of human resource, the environmental data and the cost. All of these constraints need to be also represented into this game.

12.2.1 "SimGreen" Game Rules

The "SimGreen" is designed as a strategic and collaborative game by multiple players. All players are regrouped to represent several "companies". There is the competitive relationship between them to gain the final award - "Greenest Company". For animating the playing process, for each company, there is a "Game Master" who presents the rules, explain the objectives and pilot the rundown of this game.

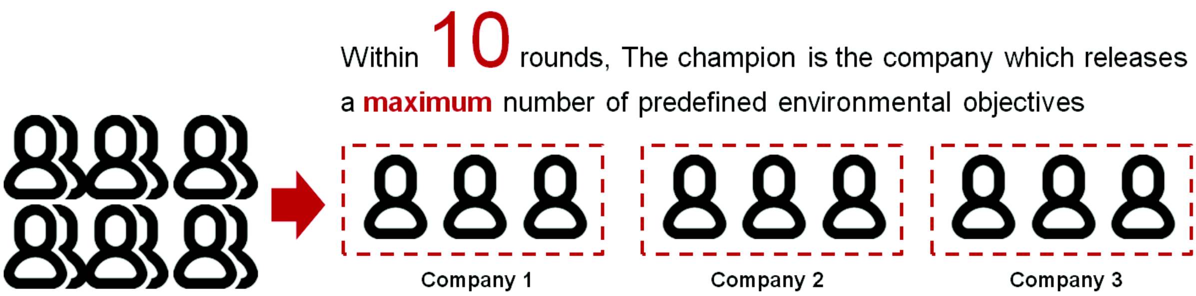


Figure 12-1: The organization of players for the "SimGreen" serious game

In reality, the environmental success of a company could be evaluated by different manners. But in this game, the definition of the "Greenest Company" is simplified as the company which integrates the maximum number of environmental issues (**Hypothesis 1**). So in order to obtain this award, each company needs to implement the maximum number of pre-defined environmental objectives within 10 rounds, each round presents 1 year. In order to realize an objective, a set of actions have to be realized. So, each participant regrouped into a company needs to cooperate with others to decide about the different actions group to be realized depending on the available resources. In order to validate if the proposed cartography could provide a systemic view of all different potential solutions and ensure finding out the common operational trajectories, this serious game proposes several usual environmental objectives to demonstrate the results.

9 environmental objectives have been listed and require the company to fulfill them. These objectives cover some hot-points of environmental related aspects which include the compliance of environmental laws, the life cycle analysis, the streamlined life cycle analysis (the carbon footprint) and the improvement of some special environmental topics.

Objective 1	Improvement of product-oriented life cycle performance

Objective 2	Utilization of recycled materials in new product
Objective 3	Improvement of product's end of life recyclability
Objective 4	Responsibility of REACH Declaration
Objective 5	Responsibility of WEEE directive
Objective 6	Green supply chain management
Objective 7	Improvement of product's life cycle environmental efficiency
Objective 8	Carbon footprint calculation
Objective 9	Environmental management system

Table 12-1: 9 pre-defined environmental objectives of "SimGreen" game

According to the preparatory studies on the proposed environmental cartography, nine scenario maps have been also prepared to illustrate all potential trajectories for fulfilling each environmental objective. The mechanism and the format of these maps are the same than with the "tracking back" mechanism. The next figure 12-2 indicates an example of scenario map for the first predefined objective – "Improvement of product-oriented life cycle performance". Once the company unlocks this objective, the game master provides this map to them to support the generation of trajectories.

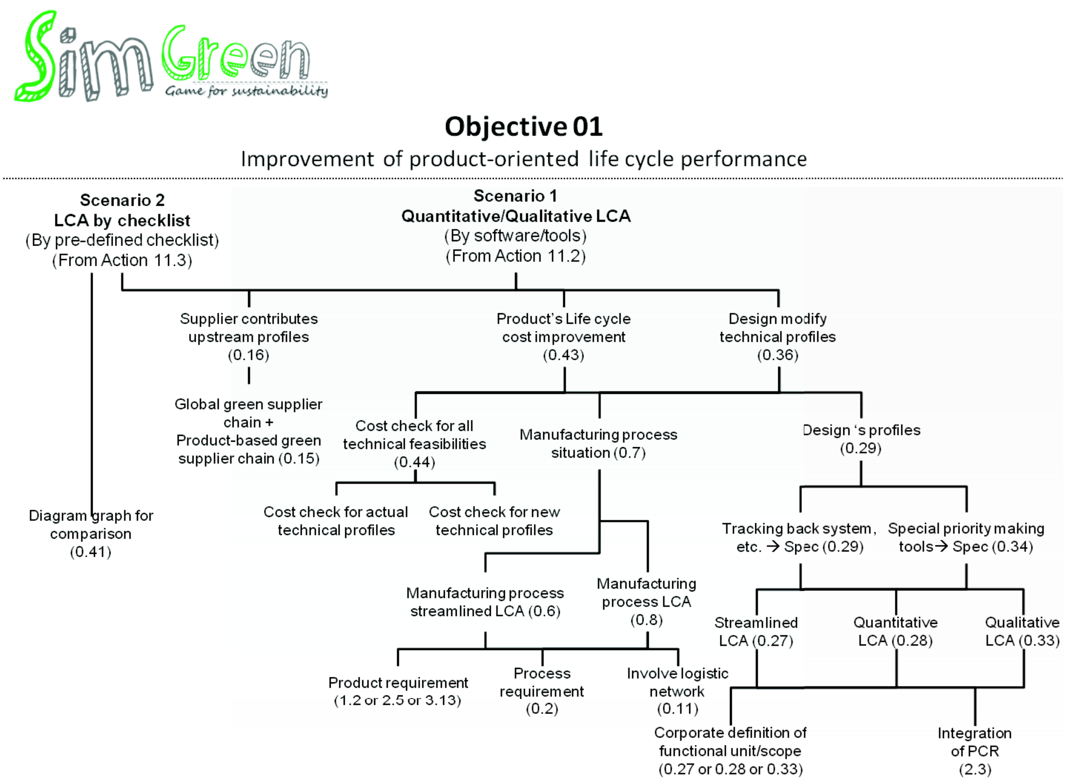


Figure 12-2: The summary of Scenarios for Objective 1 of "SimGreen" Serious game

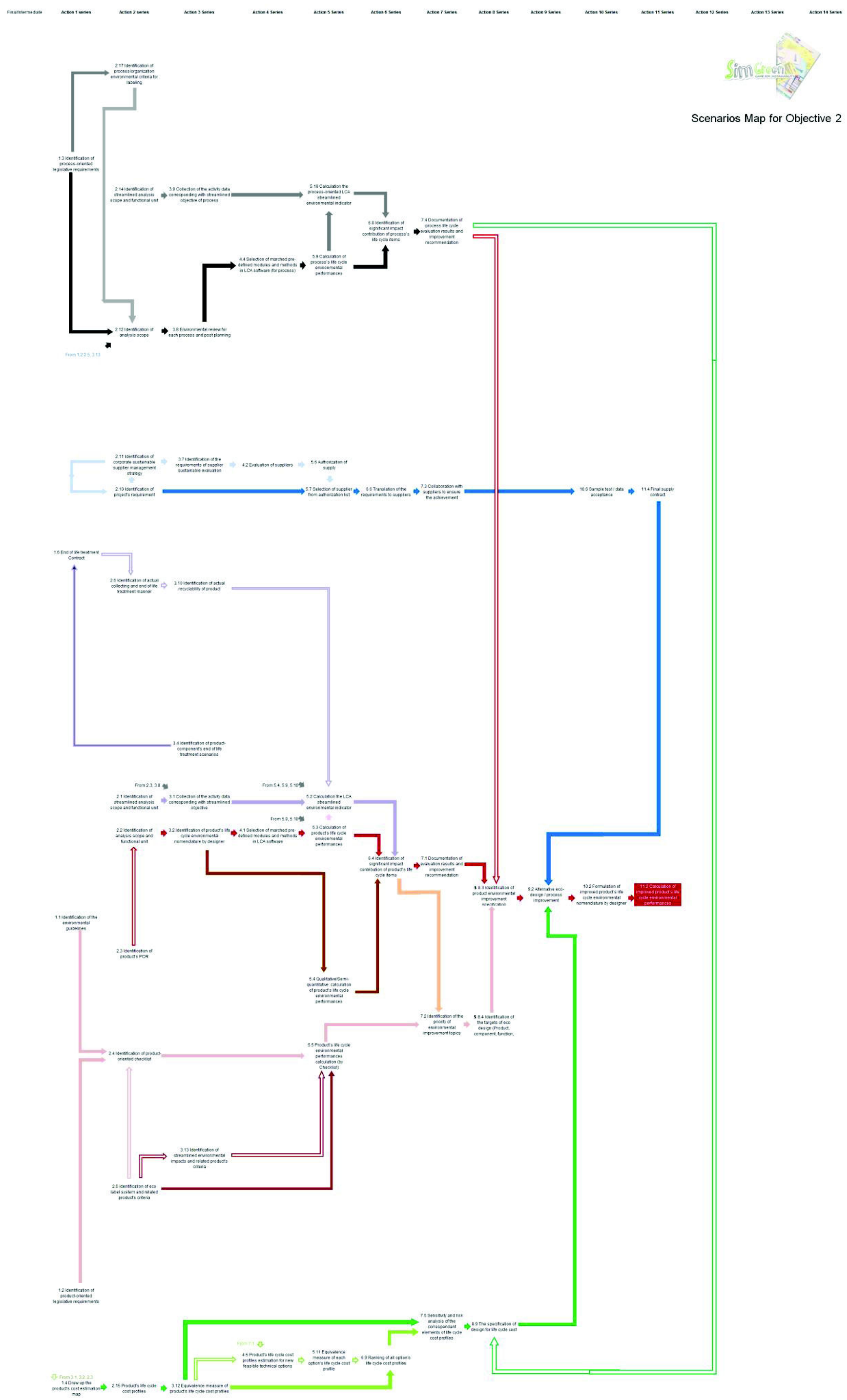


Figure 12-3: Scenarios map for Objective 1 of “SimGreen” Serious game (Hypothesis 2)

Each company is defined as it doesn't have any knowledge to resolve the required environmental objectives. So the company needs to pay some "operational sources" to analyze and find out the solutions for treating them.

Meanwhile, although the solution has been found and selected, in order to fulfill the selected one, it needs also some "operational sources" to realize all required actions inside the company. In real case, the implementation requires different types of resources, such as the knowledge for using the tools, the expertise, the time and the financial support. But in order to simplify the game rules for this first version, these different types are unified as the "operational sources" (**Hypothesis 3**).

For integrating the dynamic resource, at the beginning of each year, the company needs to **dice** to identify how many new operational resources are available and could be used for this year (this round). These resources are used for buying the scenarios map and implementing the selected solution. In this phase, the price of each environmental objective and action are fixed. In order to unlock a new objective and obtain the related scenarios map, each company needs to pay 3 units of operational resources. The company has also the right to unlock multiple environmental objectives in a round, if it has enough resource. According to different scenario, a completed environmental cartography is offered to each company to explore different trajectories which includes a series of actions to be implemented. Each action of the trajectory requires 1 unit of resources to implement it.

Meanwhile, at the beginning of this game, a completed environmental cartography is provided to each company. This completed version of cartography is to register the implemented environmental actions and highlight them. With this information, when the company plans an environmental objective, all implemented actions could directly reduce the required number of operational resources of certain trajectories. The different company selects different trajectories, so this reduction is dynamic that represents the dynamic corporate context. Due to the different applicative domains and the human resources, in real case, it's not absolute free to re-implement the actions that have been done. But in order to simplify the game rule, in this version, the game presumes that the company doesn't need to pay any supplementary resources when the next trajectory of new environmental objective requires also these implemented actions (**Hypothesis 4**). This definition ensures that the company could profit the results from the existing achievements to simplify the new environmental works. With the support of the scenarios map and the situation about the implemented actions, the player can make the selection according to the analysis of all trajectories and the required quantity of operational resources for each trajectory.

It's necessary to mention that all environmental trajectories explored by the scenarios map are considered as the equivalent solutions for pre-defined objectives (**Hypothesis 5**). The operational risks lied with thus trajectory (its means that in real, this trajectory is not realizable based on the actual context) and the finale influence on marketing are not considered and involved into the selection. By considering only the available operational resources, each company selects a suitable trajectory and implements it to fulfill the selected objective.

12.2.2 "EVENT" and "Chances" cards

Additionally, in order to present the real influences from the external emergent requirements and the internal corporate changes, in order to add the uncertainty of the game process, the "EVENT" and "Chances" card have been defined which modifies the environmental objectives and the quantity of the available resources.

The idea of "EVENT" cards is to represent the external emergent requirements for all companies. The emergent requirements mean that company is required or suggested to treat some environmental topics which have not yet been planned in-company. These requirements include the mandatory needs and some voluntary needs. The mandatory needs, for example, include new published environmental laws. The voluntary needs present if they are implemented, the company might gains some new benefits to support the corporate development. In really, company could firstly publish an environmental declaration to affect the industrial standardization or the company might join some scientific researches to gain the best solution before the competitors. In this game, the mandatory needs require that several environmental actions must be implemented in a short time period, such as the company must prepare an "end of life instruction" in two years (two rounds) to simplify the recycling process. The voluntary needs are defined as the achievement of these requirements that could gain some supplementary "operational resources", such as: the first company publishes an "environmental declaration" that can gain 4 units of "operational resources". The "EVENT" card pushes the players to face multiple environmental objectives at the same time (mandatory emergent events and the predefined environmental objectives. Under the limited operational resources, this situation encourages the players to try to find out more efficient trajectory by exploring common actions or by using parts of the implemented trajectories.

In this version 12 “EVENT” cards are proposed: four cards require the mandatory events; three cards voluntary events require some supplementary environmental objectives to be fulfilled and five “blank cards” which don’t bring any new events. These “EVENT” cards are picked out at the beginning of each round (since second round) by a game master and this picked card affect all participant companies.

Mandatory EVENTs	
Enforcement of EN 15804	**Context**: New European law EN 15804 defines new environmental declaration rules and related product’s category rules for construction and electric/electronic goods. **Requirements:** ▪ Quantitative LCA should be done in 2 rounds ▪ Environmental declaration should be done by new PCR - If Quantitative LCA isn’t done - ▪ Need 3 units of operational resource to learn the new rules - If quantitative LCA have been done – ▪ Need 1 unit of operational source for modifying the PCR and generating the final declaration ▪ Need 1 unit of operational source for modifying the environmental inventory
Regional green contribution	**Requirements:** In this round, company should implement the actions in order to analyze the global performances of manufacturing process
Calculation of product’s recyclability rate	The industrial association requires an industrial survey for recyclability rate of product. Till to next round, the initial calculation of recyclability rate should be done
Preparation for “Energy management”	The company should finish the process - oriented life cycle cost analysis in next two rounds
Voluntary EVENTs	
Needs of product’s environmental declaration	The first company which completed fulfills the objective – product’s environmental declaration, could gain 2 units of operational source
Needs of product’s carbon footprint Standardization	The first company which completed fulfills the objective – product’s carbon footprint , could gain 4 units of operational resources Other companies needs 1 unit of operational source to modify the PCR
CIRP conference	Each company communicates one implemented trajectory. All participated companies learn this trajectory without the resources
Blank Cards	
Nothing happen	

Table 12-2 The “EVENT” cards of “SimGreen”

Meanwhile, beside of the modification of the external requirements, the “Chances” cards modify the internal corporate events. The idea of these cards comes from that the special corporate events influence environmental integration. These special events includes the particular exigencies from main customers, the motivation of employee (The establishment of environmental department, etc.) and the change of corporate organization (Ex: the arriving of new boss bring some new ideas which might influence the implementation of actual program) and the human resources (the resign and retirement of environmental expert, for example). So finally, these influences are presented as the modification (increase or reduce) of the quantity of operational resources in this game. And this modification might further push the players to adjust the selection of environmental trajectory facing the new internal operational conditions.

18 “Chances” cards are prepared. A player represents the company to pick out a “chances” card at the beginning of each round (since third round) and the picked card only acts on thus company.

Special required actions to be done	
Negative performance of waste collection by third party	▪ The take-back system should be self done by company
Contribution for Green Marketing	Marketing department requires a product’s environmental declaration.
Emergency from customer	Customer requires company to fulfill the objective “product’s LCA calculation” in two rounds.
Emergency from investor	Investor requires company to provide the report of the process-oriented and product-oriented life cycle cost analysis’s results at the end of the next two rounds
The increase of operational resources	
Collaboration with a scientific research laboratory	+ 3 units of operational source
Waste collector is financed by regional government	▪ - 1 required operational source if the waste take-bask system is implemented by a special external end of life treatment contract ▪ Available during 2 rounds
Participation of Eco’DEEE	+ 3 units of operational source for actions concerned with “End of life”
ANR/ADEME partner	+ 2 units of operational source
Positivity of suppliers	In this round, any action concerned with suppliers/partners don’t require any operational sources
Welcome new boss of eco-design team	+ 1 unit of operational source
The reduction of operational resources	
Retirement of environment expert	- 3 units of operational resources
Financial crisis	- 6 units of operational resources
Negativity of suppliers	In this round, requires 1 unit of supplementary source, if the action concerned with suppliers have been done
Operational mistakes	- 1 unit of operational resources
Fail of research	- 2 units of operational resources
Corporate reorganization	- 2 units of operational resources
Blank Cards	
Nothing happened	

Table 12-3: The “Chances” cards of “SimGreen”

The “chances” card proposes four different types of corporate events: 1) four special required actions to be done for only this company; 2) six cards are for increasing of operational resources; 3) six cards are for reducing the operational resources; and 4) two "Blank cards" present "nothing happened".

12.2.3 The rundown of "SimGreen"

Finally, a rundown of this serious game is presented in table below 12-4. This rundown includes the roles of each actor and the playing process of 10 rounds.

Round	Game Master	Players
0	▪ Presents of game rules ▪ Provides pre-defined objectives list ▪ Provides game supports	▪ All players are regrouped into several companies
1 And 2	▪ Presents scenarios map ▪ Helps the generation of potential trajectories from cartography ▪ Explains trajectories	▪ Dice for quantity of operational source for this year ▪ Identify which objective(s) to be unlocked ▪ Explore potential trajectories ▪ Analyze the quantity of required operational resources and the relationship among different actions ▪ Identify the suitable trajectory (s) for fulfilling the selected objective (s) – decide the actions to be done
3	▪ Presents "EVENT" cards ▪ Takes out an "EVENT" card ▪ Repeats actions in round 1	▪ Analyze the requirements from "EVENT" card ▪ Repeat actions in round 1
4	▪ Presents "Chances" cards ▪ Modifies quantity of operational resources according to "Chance" card ▪ Repeat actions in round 2	▪ Take out a "Chance" card for this company ▪ Repeat actions in round 2
5 …… 10	▪ Repeat actions in round 3	▪ Repeat actions in round 3
11	▪ End of game, account result ▪ Summary of the game about the different scenarios selected	

Table 12-4: Rundown of "SimGreen" game

12.3 Implementation of this serious game and discussion of feedback

Four sessions have been organized to implement this serious game "SimGreen". The first session was organized, on 14 January, 2013, into the intern seminar of CPP of laboratory G-SCOP. Twenty scientific researches about environmental management, eco-design and optimization of production process were organized in order to validate the contents of this serious game. This session lasted 2 hours and all participants were regrouped into three companies. Due to the limit of time, this serious game didn't run over. Almost all three companies arrived at the round eighth. But the principles of “SimGreen”, the game rules, and the playing process have been presented in detail.

The second session was organized on 7 November, 2013, with environmental experts from IFTH (French Textile and Apparel Institute). The objective of this session was to validate the pertinence of all proposed contents. The detailed description about the actions’ chain of each trajectory has been presented. Due to a vast number of discussions, this session lasted 4 hours and all participants represent only one company to realize the objectives.

Figure 12-4: The photos of the organized sessions for implementing “SimGreen”

The third and fourth sessions were organized for the course of master degree about “Environmental management” in INPG (National Institute of technology of Grenoble) on 21 and 28 November, 2013. 36 students of master degree participated into these two sessions during 3 hours.

The principle serious content of this “SimGreen” is to present a new conception about “At the beginning of planning stage, a systemic view of the potential trajectories and states of required resources could optimize the decisional process about the integration of the environmental activities” By analyzing the observations during the playing and the final feedbacks from all participants, several points have been summarized below to validate how the "SimGreen" serious game answers the requirements.

12.3.1 Use of the game by experts

The first two sessions were organized to play with environmental experts in order to validate the pertinence of the contents, both for serious game and for cartography. Indeed, the serious game is based on the database proposed for the environmental cartography. So, this experiment was the first step for the validation of the proposed approach.

By the description from the game master, the experts from G-SCOP laboratory and IFTH discussed with the author about each trajectory for 10 environmental objectives. During the second session, an expert of IFTH about the environmental methods and an environmental program coordinator were involved into the discussion. This session lasted 5 hours to assure a full discussion. During the discussion, they pointed out that the proposed cartography and scenarios maps could directly support the company to take a more systemic view about the potential solution. Especially, the 46 environmental topics, 122 units of actions and 186 interactions among different environmental topics might ensure the generation of the different trajectories. Meanwhile, the detailed actions chain of each trajectory is easy to understand. Practically, the company might directly refer the scenarios maps to resolve its environmental problems. Finally, the pertinence of the proposed contents has been validated by thus experts. Meanwhile, they brought also some new examples to prove the explored actions.

12.3.2 The systemic cartography improves the integration of multi-objectives

During the playing process, the participants indicated that the combination of different scenarios maps can support the company to find out a most efficient trajectory to answer the multi-objectives. An example was observed directly during the first session for intern seminar of G-SCOP laboratory. For a company (named as company A), in the fourth round, the company needs to finish the objective preselected in third round: the environmental management system for production's process. According to the scenarios map of this objective, several potential branches can be selected (details presented as below Figure 12.5).

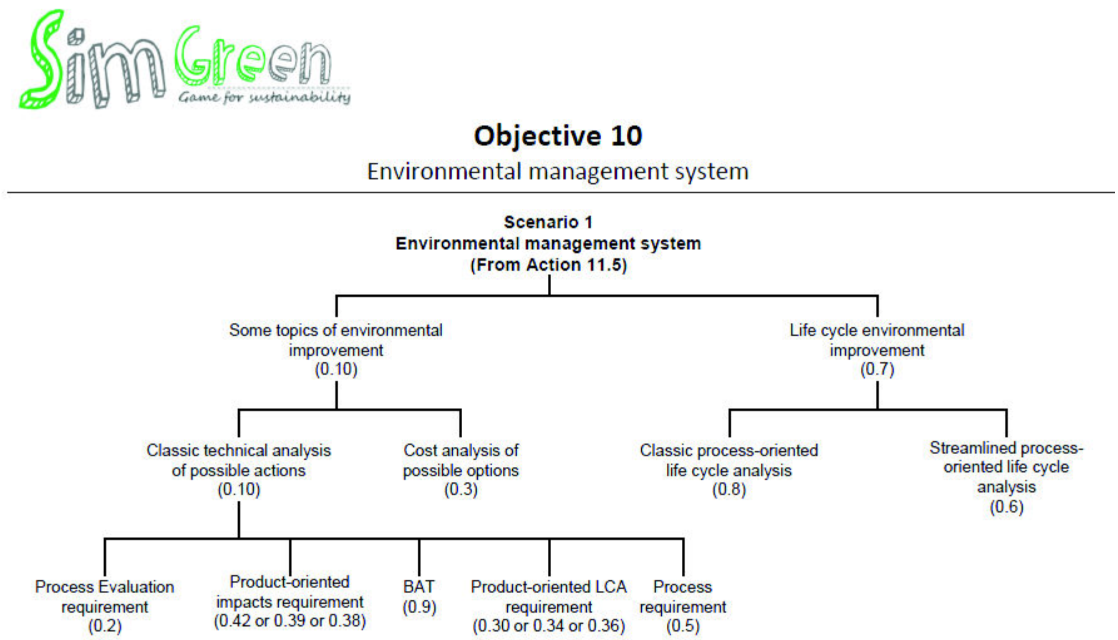


Figure 12-5: The scenarios map for the objective: environmental management system

Without any achieved environmental activities, at macro level, the company might either launch the classic environmental management system according to the check list of factorial activities, or take a life cycle analysis of the production process[40]. Secondly, there are two different targets for launching the classic management system, either for compliance with technical requirement, or for improving the financial performance of production process. In practice, the first compliance contributes to the ISO 140001 certification or participates into regional environmental improvement program. Second branch show the different point of view, this analysis focuses on the cost profits of significant working process and find out the solution by the environmental protection solution. Meanwhile, a set of technical elements could be considered, the BATs (New best Available Technology), the requirements for product's improvements and the process-oriented improvement.

Facing these options, the players of "company A" discussed together in order to make a decision. Some of them wanted to take the trajectory following the financial cost review and some others wanted to take the process-oriented LCA. The both selections were correct and game the master didn't judge these decisions. But at this moment, the Game master and a player of this company picked out two cards: the "EVENT" card required a "review of actual production process to contribute the local survey in this round", and the "Changes" card

[40]Due to the limit of actual LCA software, the environmental data registered into its database bases on the secondary data from industrial average level. So it's not necessary to collect the primary data of real process for launching the process-oriented LCA.

indicated that “the marketing department requires a sheet for an environmental declaration” to contribute to the business competition.

Facing these three environmental objectives at the same time, the “company A” reconsiders all potential trajectories. According to three scenarios maps, the player find out that “the classic environmental management system oriented the technical improvement” could directly answer three objectives within the minimum operational resources. This trajectory has covered the actual production process review as the first step; and then the results of this type of activities could be directly integrated into the product’s environmental declaration, because the production process is a phase of product’s entire life cycle. Any contribution at this phase affects the final results of product’s environmental achievement.

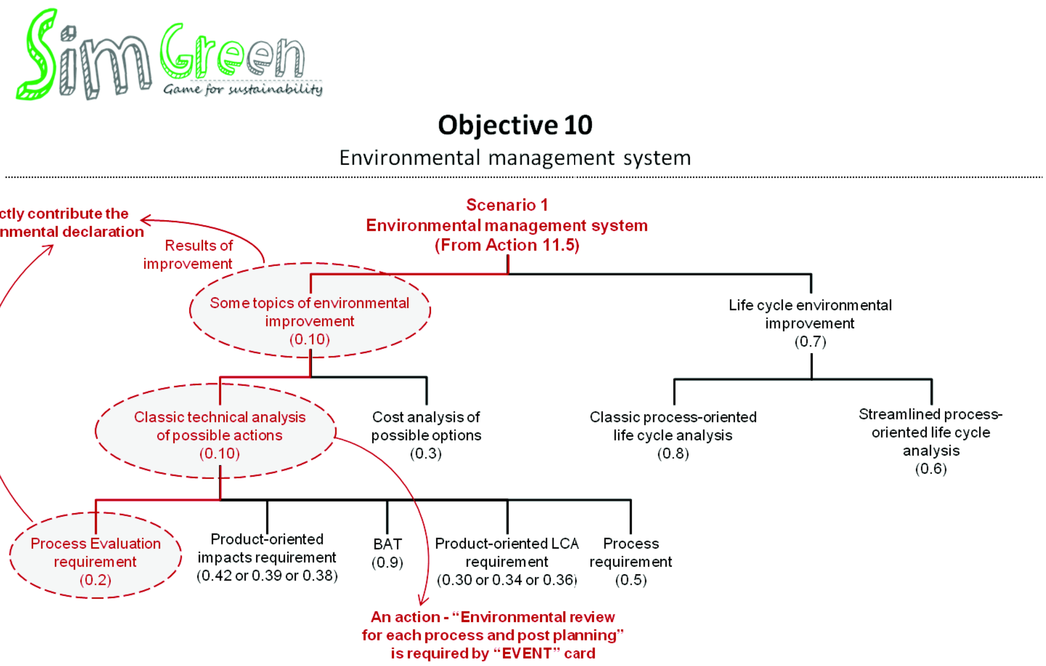


Figure 12-6: The choice of company A to answer three different objectives at the same time

On the other side, the author observed that in previous phase, another company (company B) has implemented process environmental management via the approach of “Life cycle analysis”. So facing this new “EVENT” card, they could not find out the common trajectory for two objectives at same time, so this company realizes a different solution: “Process-oriented LCA” plus “production process review” which require 2 supplementary units of operational resources. The real environmental impacts of the process into the company could certainly help to validate and update the definition of LCA. The integration of the primary data will ensure results for LCA that are more justifiable.

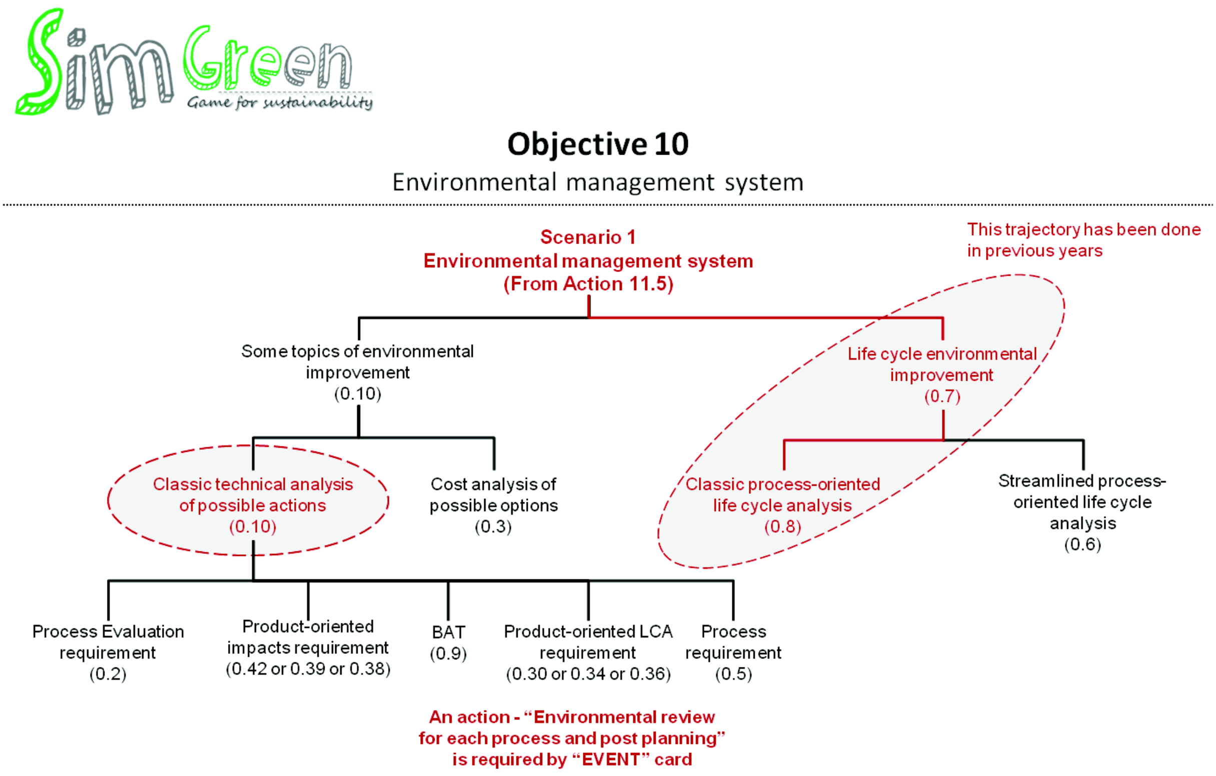


Figure 12-7: The selection of company B to answer the needs from "EVENT" card

It's interested to notice that although in this round, the company could not profit the actions that have been done; these implemented actions are also usable for some last round. With the support of existing process-oriented LCA, the company B selected "to make some process-improvement" for contributing to the product-oriented LCA improvement. But on the other side, without this previous experience, the company B selected the classic solution for product's LCA improvement.

The following summary indicates that the dynamic selections generate the different implementing results.

Company A:	Company A realizes a classic environmental management system (such as ISO 14001) to manage the production process. For this company, the environmental declaration focuses on the improvement into production phase. Meanwhile, it realizes the classic LCA for product.
Company B:	Company B realizes the process-oriented LCA to manage the production process. An environmental review of each sub-process provides the primary data to update the calculation. Meanwhile, it profits the implemented works for process-oriented to realize the product-oriented LCA (the improvement of product depending on the requirements of process improvement), and finally, the environmental declaration

Table 12-5: The summary about the playing results of a session of "SimGreen"

This example demonstrated that the cartography provides several different solutions to realize the environmental objectives. With the support of the scenarios map and the "interactions" among different actions, the company can find out a particular solution according to its context (In this game, the context is presented as the number of available resources and the actions that have been done). Meanwhile, each new selection might also dynamically influence the next implementation. So finally, these different selections for each environmental objective lead to the dynamic results of implementation.

	Improvement of product-oriented life cycle performance	Utilization of recycled materials in new product	Improvement of product's end of life recyclability	Responsibility of REACH Declaration	Responsibility of WEEE directive	Green supply chain management	Improvement of product's life cycle environmental efficiency	Carbon footprint calculation	Environmental management system
Improvement of product-oriented life cycle performance									
Utilization of recycled materials in new product	Supplier control								
Improvement of product's end of life recyclability	LCA for recyclability Supplier control	All design for X could contribute all two needs							
Responsibility of REACH Declaration	Streamlined LCA + Supplier control	Supplier control	Supplier control						
Responsibility of WEEE directive	LCA for collaboration with recycler	All design for X could contribute all two needs	All design for X could contribute all two needs	NO					
Green supply chain management	Supplier contributes the LCA	Supplier control	Supplier control	Supplier control	NO				
Improvement of product's life cycle environmental efficiency	Common part - LCA	NO	NO	Streamlined LCA	LCA	Data collection			
Carbon footprint calculation	Streamlined LCA + Supplier control	NO	NO	Streamlined LCA + Supplier control	Streamlined LCA	NO	Streamlined LCA		
Environmental management system	Integration of product's LCA into Management system Integration of management achievement into LCA	NO	NO	Streamlined LCA	LCA	NO	Product oriented LCA	Streamlined LCA	

Table 12-6: The common trajectory between two different objectives

An analysis about the combination among nine pre-defined objectives is listed into the above table 12-6. This analysis indicates this cartography at macro level could explore the most economic trajectory for several combinative objectives. An example presented as the approach of "streamlined LCA" could directly answer the needs of "REACH compliance" and also the requirements for environmental efficiency improvement. Meanwhile, the approach "Supplier controlling" provides a large support for "life cycle improvement[41]", the

[41]The productor presumes that the manufacturing process of the final product presents a low environmental impact. In real case, this situation appears when the manufacturing processes of final productor only assemblies the components from the suppliers, such as the mark owner of clothes, the productor of domestic electric machine, etc. So all intern processes are ignored. Meanwhile, the supplier's performance present a part of product's environmental impacts, so without any intern improvement of product's design and manufacturing, the "supplier controlling" might directly support the "improvement of product's life cycle environmental performance."

"REACH compliance[42]", the "Carbon footprint calculation[43]" and the "improvement of environmental efficiency[44]".

12.3.3 The systemic cartography improves a global review about the potential contributions from existing environmental practices to integrate new programs

In order to notice the implemented actions, some color pens are provided to participants to highlight these actions on the cartography. Imaging the previous example in section 12.3.1, if "company A" has implemented the "classic environmental management by considering technical improvement", when the new "EVENT" card arrives to require an "actual process review", the achieved environmental data could be directly profited. The second example was observed also during the internal seminar of G-SCOP laboratory. The above noticed "company B" realized the "management system" via "process-oriented life cycle analysis". So when it faces the problem for "environmental efficiency" of product, the pre-implemented process-oriented LCA can directly be used to prepare the reference of cost consideration. So it's different with other companies: this company implements the "environmental efficiency" of product via the "improvement of manufacturing process", not via the classic product's LCA.

This expertise and the examples demonstrated that the coupling of the trajectories assures also profiting the existing environmental practices to integrate new programs.

12.3.4 The systemic cartography ensures the positive relationship between the playing success and the targeted contents.

Why we need to explore the common trajectory for multiple objectives? Why we need to profit the existing implemented actions for new needs? A principal reason is the limit of operational resources. Meanwhile the author of serious game presumes that the systemic view of all potential solutions could optimize the environmental integration within the dynamic operational constrains. And this hypothesis is the final purpose of this serious game. The

[42]The REACH compliance requires the certification of a whole product, which could be considered as for all components. So if the final manufacturer doesn't produce any new material, the certification from suppliers is enough to answer the REACH directive.

[43]Similar with the first reference, the manufacturer presumes that the manufacturing process of the final product presents a low environmental impact. So all intern processes are ignored. Meanwhile, the supplier's performance present a part of product's environmental impacts, so without any intern improvement of product's design and manufacturing, the "supplier controlling" might directly support the "carbon footprint"

[44]Meanwhile, the supplier's performance present a part of product's environmental impacts, so without any intern improvement of product's design and manufacturing, the "supplier controlling" might directly support the "environmental efficiency improvement"

previous discussion demonstrated that the game rule and the cartography ensure the possibilities of selecting the suitable trajectory by considering the limit of operational resources which represents the dynamic constraints. And then, step by step, this serious game tries to set up the positive relationship between the playing success and this main purpose.

The first round, without the “EVENT” and “Chances” card, is designed to present the game rules and how to generate the operational trajectory. In this round, there are not implemented actions, nor the multiple objectives[45]. The players only focus on the trajectories’ generation and establish the relationship between the trajectory and the different required quantities of operational resources. The implemented actions are noted on cartography.

Starting from the second round, the players have the chance to consider the existing implemented action to reduce the cost of new integration. Once they find out this relationship, they could directly gain the advantage, and the game rule enforces nine times to strengthen this conception. Meanwhile, starting from the third round, the integration of “EVENT” cards brings the mandatory consideration about the treatment of multiple objectives. Based on the limit of operational resources, the players have the opportunities to find out the common trajectory is better than two independent trajectories. And then, the “Chances” cards are involved from round 4 which further modify the quantity of required environmental objectives and the operational resources. This type of modification encourages the players to generate the environmental trajectories by considering the resources.

Beside of these points, the game rules encourage the player to generate the trajectories by themselves. With the description of game master for all 46 environmental topics, this serious game provides an opportunity to provide the lessons about a global state of art for environmental methods and practices. And it set up a first image about the collaborative relationship among these different methods.

12.4 Perspective for next version of “SimGreen”

Serious game “SimGreen” achieves the original purpose which requires the player to optimize the trajectory selection by considering the multiple objectives and the limit of operational

[45]Game rules allow the players select multi-objectives in first round. But in practice, in order to simplify the first step and encourage the player to focus on the mechanism of trajectory’s generation, the game master proposed the company to select only one environmental objective to be treated.

resources. In order to improve the efficiency of this game, some perspectives are presented in the paragraphs below.

12.4.1 Benefits of implemented environmental actions need to be reconsidered

In this version, the implemented actions mean the related knowledge has been obtained and the necessary resources have been used. So for all new objectives, the company doesn't need any supplementary cost for re-implementing them. But in practice, it's not true. The knowledge could be inherited, but the implementing resources, such as human resources and software licenses are also necessary to be paid. Meanwhile, event for same approach, the same method or process used into different domains requires some additional researches to make the adaption. For example, the material flow analysis (for REACH compliance) and the carbon footprint are all covered by an approach of "the streamlined life cycle analysis". Even the mechanism, method and tools are similar, it's necessary to add some operational resources to collect the related environmental data and adapt the tools into new domain. Thirdly, in real practice, some update of directives or industrial standards requires some new workload for implemented actions. The typical example is from the REACH compliance. In order to comply with the REACH directive, it's mandatory to analyze the contents of SVHCs[46] in the product. But this substance list is frequently updated by European Chemical Agency. So even if all environmental actions related to REACH compliance have been done, it's required to repeat the same process for treating the new added substances. But although if the technical actions and total process are required to be re-implemented, the company might make a quick response for all update with a comprehensive forward looking for all problems.

Facing three points, the next version needs to modify the game rule about how to profit the implemented actions to adapt the real practices.

12.4.2 The multi-types operational resources need to be considered

In order to simplify the game, the different types of resources for implementing actions are uniforms and described as "operational resources". The cost of each action is equivalent; a unit of operational resource unblocks an environmental action. In practice, multiple types of operational resources are required to implement an environmental action, such as the human resource, the knowledge, the required cost and the time. These resources could be transferred

[46]SVHC: Substance Very High Concern, it's a substance list is attached into the annex of REAH directive. The productor must evaluate and declare if its product contains the substances of this list. Some substances of list are prohibited to use or used with license.

between them, such as the company might pay the sub-treat contact to involve the external intelligence to gain time and knowledge. For some no-urgent problems, it is also possible to save the cost to prolong the implementing time, etc. Meanwhile, in this version, the implementing cost for each action is equivalent; an environmental action requires a unit of operational resource. So the cost of different trajectories is accounted by the numbers of required action. This hypothesis leads to a bad situation, the cost of classic LCA is less than some simple approaches “Design for X”. But in practice, it’s inverse.

In order to resolve these two problems, in the next version, the game rules need to consider the mechanism that can integrate different types of resources. And then the rules allow some translation among them to adapt different corporate needs. Meanwhile, it’s necessary to identify different implementing cost for all actions. This definition might better represent a real case.

12.4.3 The complexity of the game need to be considered

Some players indicated that this serious game is very complex. Especially, it’s very difficult to generate all trajectories and compare them by using the actual game supports. Some game masters report also that the large number of interactions leads to the fact that the generation of all trajectories is impossible. And this hard work de-encourages the players to continue. Meanwhile, a game master indicates that the animation of this game needs a systemic knowledge about the state of art about large number of environmental approaches. He asks a detailed description or practical examples for all interactions. Facing these problems, the development of a digital version of this serious game will be realized. With the support of computer technology, it’s easier to generate and compare the trajectories. And also the description registered into the database might provide some detailed presentations about the interactions and related methods. Meanwhile, the digital version will support also the integration of multiple types of operational resources and the different implementing costs for all actions.

12.5 Conclusion on this experiment

In order to validate if the proposed environmental cartography and the “tracking back” mechanism could provide the company with a systemic intelligent support for optimizing the efficiency of environmental integration, the first experiment was defined to develop a serious game, “SimGreen”. The principle purpose of this game is to push the player to identify a suitable trajectory by considering multiple dynamic objectives and the limit of operational resources. So nine normal environmental objectives have been selected and the game requires the players to realize them in 10 rounds with some constraints of resources. In order to simplify the game, the different types of operational resources have been regrouped in a unique type. The different company strategic needs[47] are ignored in this game. Meanwhile, the “EVENT” and “Chances” cards system provide the mandatory opportunities to treat multiple objectives at the same time and modify the quantity of available resources. In order to validate the pertinence of the proposed contents, four sessions of the game have been realized with environmental experts (from G-SCOP laboratory and IFTH) and with master degree students. With the numerous discussions about the action chains of each environmental objective, the environmental experts proved that the proposed cartography and scenarios maps could correctly support the company to take a more systemic view about the potential solutions. Especially, the 46 environmental topics, 122 units of actions and 186 interactions among different environmental topics might ensure the generation of the different trajectories for realizing the environmental objective. This systemic view of various solutions ensures the company to select an adaptive trajectory depending on dynamic context and in actual version, depending on the limit of one type of operational resources. When company faces multiple environmental objectives at the same time, this cartography ensure the exploration of a suitable common trajectory with minimum consumption of operational resources. Meanwhile, the implemented actions and concerned knowledge are directly displayed on the cartography which ensures profiting them to further reduce the cost.

Secondly, as a serious game, the game design ensures the players to autonomously find out this new idea: the systemic view at the beginning of the program mapping could optimize the environmental integration. Meanwhile the game rules continuously repeat and strengthen the benefits of this purpose.

[47] In this first version, all potential trajectories of an environmental objective are equivalent. The influence for product marketing, the performance to attract the customs and the time pressure are ignored. The economy of operational resource is considered as the single criterion of selection.

Chapter 13 - Experiment N°2 Deployment of the "Tactic module" of Convergence project into Quiksilver

This chapter is to present the organization, the process, the results and some feedbacks about the experiment of the "Tactic module" of convergence project into the company Quiksilver. Firstly, in order to provide a clear description, the paragraph 13.1 presents the state of the art of environmental issues into the textile domain. The "environmental and healthy performance of final product" and "the depollution and the best technology during the production process" are two main aspects, which are required by some laws, directives and voluntary environmental initiatives. Meanwhile, the actual status of Quiksilver will be presented into paragraph 13.2. Some initiatives, such as the integration of recycled material, the checklist for answering REACH directive has been implemented into the company. Beside of these topics, an exemplary and experimental project, "Eco circle" has been realized to optimize the life cycle performance of a special product. Secondly, the paragraphs (from paragraph 13.3 to 13.7) indicate the details of this experiment, how this "tactic module" supports the decision about the environmental aspects' integration. Finally, the results, the discussion and the conclusion of this experiment will be presented into paragraph 13.8.

13.1 Context of sustainable development in textile industry

From a report of JEA - Japan Environment Association, the principal environmental impacts for textile industry arise from two principal topics: the material selection/production and the industrial manufacturing processes of textile product (including the dyes and some ethical issues).

Normally, there are two main categories of fibers used to produce the textile materials, the natural fibers (such as the cotton wool, the bamboo, the flax and a variety of other plants or animal based fibers etc.) and the synthetic fibers (which are material produced from petrochemicals such as: polyester, nylon and acrylics etc.). Meanwhile, facing to the more and stricter requirements from the final user, some organizations have focused on the organic natural fibers and the recycled fabrics.

[JEA, 2011] and [WWF, 2011] concludes that the "selected material" usually dictates the manners of textile design, as well as the manufacturing and the activities during its whole life cycle. So, during the design phase, a life-cycle perspective of a whole system is necessary to be addressed.

Facing the industrial manufacturing process, there is a chain of production techniques used in the manufacture of fabrics including weaving, spinning, knitting, wet treatment and sewing. Beside of the energy and water consummated, many of these processes require chemicals and dyes and thus create potentially environmentally hazardous waste products, contribute to climate change, local pollution, health toxicity (such as: Nonylphenols (NP) discharged during the spinning and dyeing phase which can interfere with sexual development in early children's life.) and may realize Volatile Organic Compounds (VOCs) into the atmosphere.

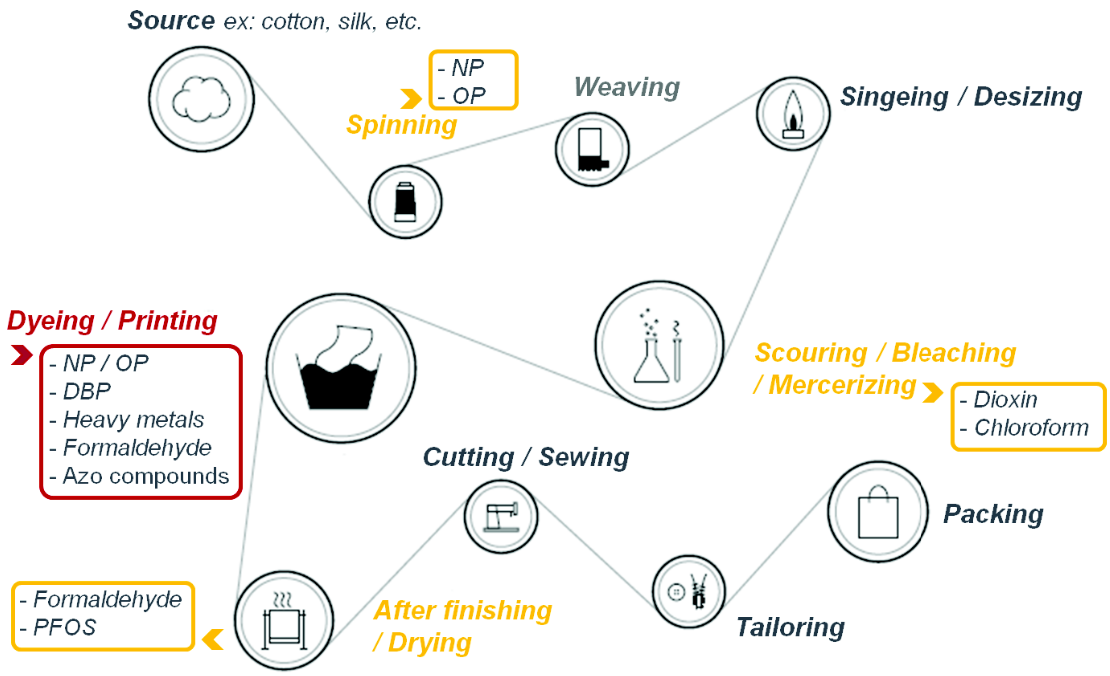


Figure 13-1: Process of fiber production and the related hazardous material flux
NP: Nonylphenols, OP: Octylphenol [Green Peace, 2010]

Additionally, the productive location of fibers is very important also to be considered. This indicator might directly affect the local environmental and social impacts (For example, some crops require more water than others, so when they are grown in areas of low rainfall they have a larger environmental impact.)

Beside of the design and production phase, the environmental performance in use phase is also significant. During the design phase, the match between the lifetime of materials and the final product's lifetime is necessary to be considered. Similarly, designing multifunctional products for a diversity of uses can also result in lower environmental impacts. And then, washing contributes a considerable amount of environmental impacts; especially those requiring detergents and hot water or special dry cleaning. It is important to consider how the clothes will be worn and washed because this will contribute to the likely impacts during the clothes' life.

[WWF, 2011] summarized that in order to reduce the environmental impacts of textile industry, a whole life cycle consideration about the pollution of all life stages is necessary.

13.1.1 European legislation of relevance for textile sector

The European commission established a set of environmental laws in order to optimize the environmental impact and reduce the pollution of textile industry.

The first environmental legislation of relevance for the textile sector is the REACH directive which requires the registration of all chemical substance, and the evaluation and restriction of the hazardous substance (SVHC – Substance Very High Concern). In this directive, all textile producers are considered as the downstream user of a wide variety of chemical products who must declare the weight or volumes of SVHCs contained and ensure a total responsibility in the management of such SVHCs according to security dash. Facing a permissible and complete forbidden list of SVHCs; the textile industry is required and pushed to modify the product's design and the tooling of manufacturing processes in order to answer the risk related to the temporary "indispensability" of certain chemicals within a short timeframe (a cause of the significant cost of reformulation and the pressing of time to market). Meanwhile, the textile industry need also to enhance the competences and working performance to efficiently evaluate and trace the volume of chemicals used, especially, the SVHCs used.

The second principal legislation is the IPPC directive (Integrated Pollution Prevention and Control). For some targeted companies, (the organizations for the pre-treatment (operations such as washing, bleaching, mercerization) or dyeing of fibers/textiles where the treatment capacity exceeds 10 tons per day), This directive requires by force the implementation of the Best Available Technologies (BAT) which has been realized in 2003. Without the proof about the implementation, the company will lose the authorization (environmental permit) for related producing activities.

Beside of these two principal legislations, the textile industry is affected by several other environmental directives such as the ETS (Emission Trading System) directive (if total rated thermal input exceeding 20MW) and those relating to waste management or to industrial pollution emissions.

13.1.2 Environmental initiatives in textile industry

Today, the customer is sensible for environmental and health impacts of products or services, especially, for clothing/textile products. In order to explicit the state of the art and the hot points of environmental initiatives in textile industry, an industrial survey about environmental certification systems has been realized. This survey collected the technical criteria of 84 eco certification systems (All related data are collected from the official website of these certification systems or textile companies) and the principal method is to calculate the ratio of percentage of listed environmental indicators - the higher ratio means this indicator or environmental topic has more attention or higher priority. Other information, such as the nature of these certifications, the main objectives, the covered product categories and evaluative methods of each indicator has been also analyzed. In order to simplify the complexity of this analysis, we hypothesize that the influence on market of each certification system is equivalent.

Firstly, according to the number of the certification, the result presents that the European market is the most sensible market for green textile. From 84 systems, 40 systems are created by the European organizations. The second place is the North-American market which establishes 27 systems related to environmental issues. Asia-pacific area presents 15 systems and the South-American presents 1 system.

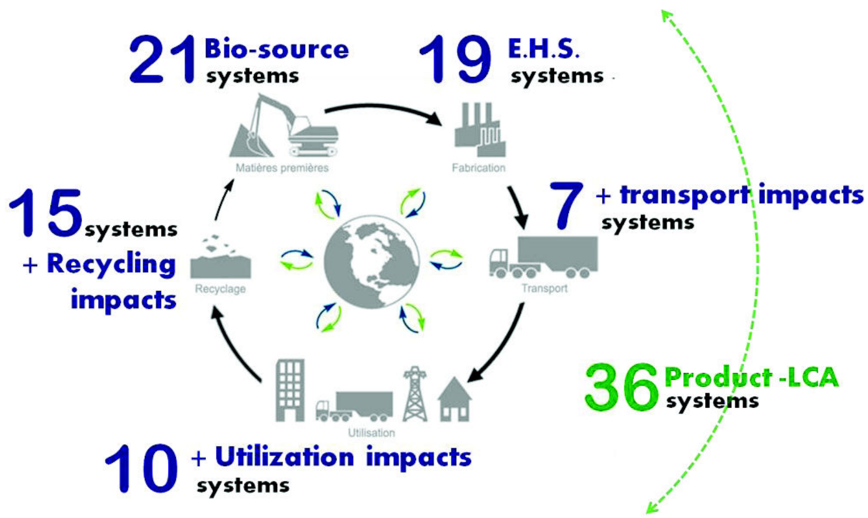


Figure 13-2: Summary of main purposes of analyzed certification systems in textile domain

If we separate these certification systems by different regions, the result points out that the Asia market focuses on the product-oriented environmental impacts (90% of analyzed certification systems (9 systems) set up the criteria for final product, just 1 system focuses on the environmental management system). But inversely, the North-American market is more interested on the bio-resource and the production process (A total of 27 systems have been analyzed, and 20 of them focus on this approach. Only 7 systems include the product-oriented approach). The most complete, the European market requires the environmental responsibilities in all both approaches.

Secondly, all life cycles of textile product have been focused on, including the source production (21 systems), the fiber and textile production (19 systems require the environmental management system), the transport and logistics (7 systems), the use impacts (10 systems require them, ex: water efficiency for washing and the resistance of coloring, etc.) and the recycling phase (15 systems). Additionally, 36 certification systems require a completed product life cycle analysis to avoid the pollution transfer.

This result presents that the "material and related productive technologies" is the main required indicator (almost 52% of all analyzed systems requires this). This indicator doesn't only focuses on the material used in the final product (ex: 44% for the forbidden additives), it also requires the material used during the production process (ex: 56% for dye process, 36% for Bleaching and 28% for shrinking). The biggest contribution is the forbidden hazardous material list from the environmental legislation (84% requires the producer should completely fulfill the legal requirements).

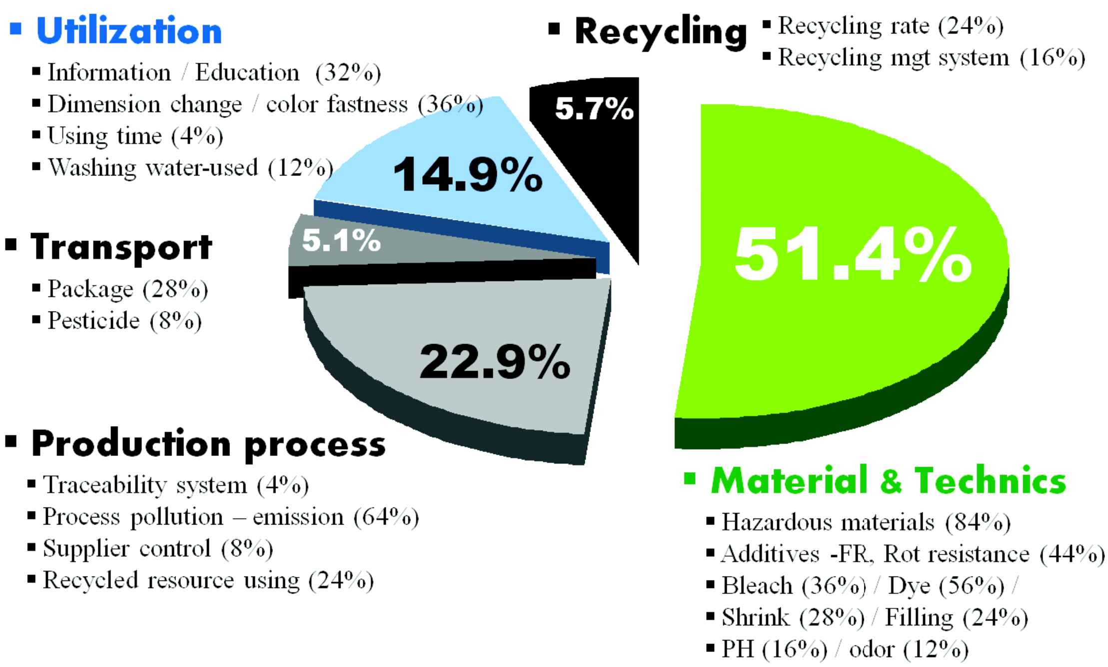


Figure 13-3: The significant environmental topics of textile industry

The pollution (in air, in water and in soil) during the production process is the second important indicator, 64% of systems establish a set of checklist to require them. This indicator does not only require the implementation of B.A.T. (Best available technology) to reduce pollution, it also needs some traversal supporting system, such as the tracking system of pollution, the supplier control, to ensure the achievement.

During the use phase, the criteria of certification system focus on two grand axes: the quality of the final product and the cleaning efficiency. The use times of the final textile product and some related characteristics, such as the dimension change because of washing and the color fastness (36%), have been usually noticed.

The end of life phase is also a hot phase. 24% of systems require the final textile product should achieve a high level of recycling rate, 16% ask a taking-back management to treat about the waste clothing. And also 24% of all systems require a proof and a minimum ratio about recycled material used during the production.

As a summary, including the design about the material selection and the industrial manufacturing process, the environmental consideration has been mentioned and required into the whole life cycle of textile products.

13.1.3 Conclusion on the general context

The above sections summaries the general context of the environmental related requirements into the textile industry. Three principal environmental directives have been enforced to require some different environmental improvements. Meanwhile, by analyzing the existing eco certification system, the results indicated that there is not a uniform definition about the "environmental product". According to different focuses, the required environmental improvements are different. Facing the number of possibilities about the environmental activities, it's necessary to create a systemic integration mechanism to select a suitable solution depending on the strategic requirements and the dynamic context.

13.2 General context and the environmental initiatives of Quiksilver

Quiksilver is one the world's leading outdoor sports lifestyle companies, which designs, produces and distributes a diversified mix of branded apparel, footwear, accessories, snowboards and other board sport-related equipment.

As the implication of the brand logo, a large wave with a mountain on a red background, since 1999, the Quiksilver Group has worked with several associations , under the slogan "Don't Destroy What You Came to Enjoy", to protect environments through a host of initiatives ranging from eco-design and environmental management. According to an in-depth analysis about the actual environmental program, the next paragraphs explain the operational context for further environmental integration.

13.2.1 The environmental initiatives of Quicksilver

In 2005, the company founded the "Quiksilver Foundation", which bases its action on environmental, educational, health and youth-related projects in order to contribute to sustainable development worldwide.

Under the program of this foundation, Quiksilver has launched a set of product-oriented environmental initiatives in order to answer the requirements from the customer's satisfaction and the corporate ambition. From 1999, Quiksilver has launched a project to integrate the bio-cotton in the product. The certificate of GOTS[48] is considered as an important tool to evaluate the quality of bio-cotton. Till now, 35% of products are certificated and labeled. Beside of the bio-cotton, Quiksilver requires 100% of its supplier to provide the certificate of OEKO-TEX 100 in order to present the environmental consideration has been focused on and implemented. This Standard is an independent testing and certification system for textile raw materials, intermediate and end products at all stages of production, which includes raw and dyed/finished yarns, fabrics and knits, ready-made articles (all types of clothing, domestic and household textiles, bed linen, terry cloth items, textile toys and more). These two works are charged by worldwide sourcing office which is a special organization for suppliers' management.

In order to answer the requirements from REACH directive and other local laws, Quiksilver prepared a corporate checklist, named "QUEST" - Quiksilver Ethical Standards of Trade, to complete the lack of the two above certificate standards. The quality team embedded into supply chain charges the identification of this checklist and evaluates the performance of supplier. Today, 100% of authorized suppliers sign the contract and fulfill the criteria.

Finally, a project "Eco circle" was implemented to initiate the environmental improvement by eco-design. This project was headed by the Sustainability & Innovation unit (S&I unit) and the product manager to encourage and coordinate the integration of environmental aspects into the design process that was supervised by the product manager. Meanwhile, several

[48]GOTS: Global Organic Textile Standard is the worldwide leading textile processing standard for organic fibers, including ecological and social criteria, backed up by independent certification of the entire textile supply chain. Version 3.0 was published on 1st of March 2011 which focuses on the high degree of ecological and social criteria about the fiber production, industrial processing and quality assurance system

external stakeholders, such as the external experts, the product's suppliers, were involved in this program in order to respond to program specifications.

This project selects a snowboarding jacket as the first product to launch the eco-design process. After studying some related situations, such as the main functional requirements, the company's skills, relationships with suppliers and some internal constraints (Typically, the schedule and cost), the project defined four major environmental improvement targets for this product:

- Optimizing material use;
- Using recycled and/or recyclable materials;
- Focusing on recycling;
- Measuring the product's life cycle performance.

Depending on these targets and the time pressure, some related environmental methods and tools were selected or developed to prepare the real initiative through the design process. Shortlists of avoidance materials and components were identified to optimize the use of materials. A checklist and a template for collecting and verifying the supplier's data had to be developed in order to measure the recycling situation; and a simplified LCA was selected to be adapted to the initiative's needs. Besides the above, a requirement and environmental profit dashboard and a skill validation process were prepared to monitor the achievement:

Project Requirements	**Stakeholder involved**	**Specific knowledge**
Eco-design training for the project team	- University of Technology of Troyes - External consultant (EVEA)	Pedagogy and eco-design, sustainability and LCA. LCA expertise
Life Cycle Analysis expertise	External LCA consultant (EVEA)	LCA expertise
Product development expertise	Project manager Project development team Material supplier (TEIJIN)	Project development expertise Specific product expertise Recycling technology Environmental knowledge
Funding requirements	Public funding (ADEME and Aquitaine region)	Funds
User review requirements	Some Quiksilver back-office employees Retail shop employees	Quiksilver and "surf" culture User/customer viewpoint

Table 13-1: Resource mobilization for the "Eco circle" program

After a series of internal trainings and seminars, the design team developed 6 sub-models to optimize the use of materials and components, such as zips, sewing, cut lines.

Due to the fact that Quiksilver doesn't charge the production process (this work is outsourced to vast numbers of Asian suppliers), the production department, including the quality team and sourcing office[49], support the R&D team contacting the potential suppliers and ensuring the balance among the product's quality, the environmental performance, the merge, the deliverability.

Finally, communication was issued to the European retail network to promote the "Eco-Circle" program and eco products. Some advertisements appeared in several stores and the international press was charged by communication team. An operation was also held in 15 European stores, collecting customers' old clothes and giving them a discount for any eco product brought.

13.2.2 Methodology for mapping the corporate operational context of further environmental integration

Quiksilver, as a large-size enterprise, has a strict organizational structure and complex collaborative processes and software platforms. In order to make a suitable roadmap of environmental integration, it's necessary to clarify the responsibilities of each corporate function, the collaboration processes among these functions, the limit and the barriers about environmental integration, and the potential relationship with the environmental program. This information presents the actual corporate situation which is the basic criterion for selecting the right roadmap.

In order to receive the detailed information about each function, a large scope interview of some employees has been organized. This interview covers various different functions, from top managers to designers and includes some external stakeholders. Finally, the daily working process among the different corporate functions, the barriers of environmental integration have been realized to highlight the knowledge streams among different stakeholders.

- Interviewees

In order to ensure data quality, according to the decision pathway of the company, this interview was addressed to the delegate of each internal function as well as the different hierarchy level agents (including top managers, managers of each section, designer and end

[49]Sourcing office: this is an independent department which treats the relationship between the Quiksilver and the suppliers. This department charges the proposition of the shortlist, notice card, to R&D team. It supports the evaluation of the sample's quality and controls the cost and delivery performance of final selected supplier.

operational people of each function). Overall, 28 interviews were conducted. The following table synthesizes the list of interviewees.

<table>
<tr><td>Top managers</td><td>Chief operational officer
Human resource director
Sustainable development director</td><td rowspan="2">Design</td><td rowspan="2">Design director x 2
Innovation director
Stylist designer
Graphic designer
Assistant of design</td></tr>
<tr><td rowspan="2">Back office</td><td rowspan="2">Sustainable development manager
Communication director
Financial controller
Jurist</td></tr>
<tr><td rowspan="2">Marketing</td><td rowspan="2">Mark manager
Marketing director
Customer service</td></tr>
<tr><td rowspan="2">Operation</td><td rowspan="2">Operational planning
Quality
Resource office
Production
Administration of commerce</td></tr>
<tr><td>Sellers</td><td>Retail network manager
Commerce director
Assistant of commerce
On line commerce
Commerce analyst</td></tr>
</table>

Table 13-2: The interviewee list of Quiksilver

- Interview support

At first, to avoid miscommunication and misunderstanding in later interviews, some corporate context analysis and glossary preparation were conducted to establish a "common language" with interviewers.

To ensure quality of feedback, a questionnaire was prepared before the interviews were launched. This questionnaire included four sets:

- The daily work of interviewees. This part focuses on the position of the interviewee (for example the general management, management, and operational work), their responsibilities (missions and objectives), and the working process (decisional flow and related tools). This set also registered the reason and nature of collaboration with other functions.
- The position and role of each stakeholder in the environmental program.
- The links between daily classic tasks and environmental activities. These links include the supports used to integrate environmental issues into classic work and the type of decisions taken. In addition, the relationship between environmental profits and other success indicators was registered.
- Their opinions of current environmental activities embedded into their daily work. Such as what is the idea activity? What are the gaps between the actual situation and the idea model?

13.2.3 The summary about the working process inside of Quiksilver

Depending on this large scope interview of each function of Quiksilver, a map of the corporate working process was realized below:

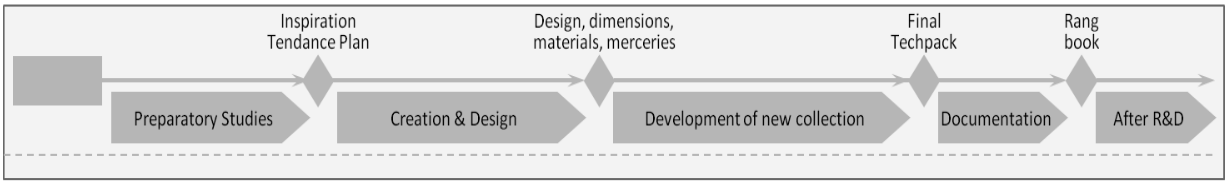


Figure 13-4: The framework of R&D process for a new collection

Step 1: Preparatory studies

The designer and grapier charge this step. The principal work is to look for the inspiration about the tendency of fashion style. Some preparatory studies, such as new color and new technologies are also analyzed in this step to support the design further.

Meanwhile, the recommendations from the marketing team, the commercial feedback are integrated into the finalization of the collection plan.

According to the working process of "Eco circle" program, the environmental requirements for certain product have to be involved into this step to update the "collection plan".

Step 2: Creation & Design

During this step, the R&D team designs the products according to the requirements of collection plan. Meanwhile, the commercial feedback of the product on sales is involved also to modify the collection plan (the model, the color and the cost requirement, etc.) and the product's design. Finally, at the end of this step, the first product design is finished, and the communicable elements about the prioritized product are transferred to marketing team to prepare the promotion plan.

Step 3: Development of collection

According to the requirements of product design, the sourcing office proposes a shortlist of some available and prioritized suppliers. R&D and Quality team evaluate the supplier by using the corporate checklist "QUEST" and the product design. During this step, some activities are realized in order to finish the product design and fix the production chain. These activities include the first evaluation of supplier, the validation of sample, the modification of product design, the negotiation with supplier and the re-evaluation, etc. Meanwhile, the cost of each decision is also considered. Finally, a document, named as “Tech Park” is prepared to notice all related technical and production data of each product.

Step 4: Documentation

During three previous steps, in the PDM (product design management) the assistant of the designers charges the update on the product’s information for each modification. In this step, the final version is registered and archived. And finally, a “rang book” is prepared to launch the commerce.

Step 5: After design

The marketing team proposes the marketing plan to support the commerce. The R&D team receives the feedback to consider the next collection.

13.3 The methodology of this experiment

In order to validate the usability of the “Vertebral Column model”, project “ANR - convergence” organized a working group, from 7 to 9 October, 2013 in Quiksilver to initial the deployment of this model. As a part of this vertebral column, the tactic module has been integrated into this deployment to contribute to a systemic roadmap of environmental integration. The members of this group are a PhD student from UTT (Technical university of Troyes) in charge of the strategic module, a PhD student from UJF (Joseph Fourier University of Grenoble) in charge of the tactic module, a corporate innovation expert for textile product and a Quiksilver design director who is in charge of the relationship between the academic institute and Quiksilver. During these three days, the working group organized several interviews with the key functions to construct the summary of corporate immaterial capitals. The idea of these interviews is to complete the necessary information of the large interview organized in 2012 about the key activities. The questionnaire includes three topics:

- State of art about the current operational governance of these key activities (processes, tools and destination);
- Existence and nature of reporting to the strategic decision;
- The nature of relationships with external/internal partners contributing to the activities

Depending on this synthesis of actual context, the “Vertebral Column model” has been implemented to identify the governance following the next timeline:

From 7 October to 9 October 2013	1. Realization of maturity profile of corporate governance by the interview and the preparatory studies of industrial and corporate context
	2. Identification of corporate business objectives
	3. Definition of strategic objectives about environment impacts
	4. Generation of the systemic tactic scenarios map to realize the strategic objectives
	5. Definition of a suitable roadmap by identifying the right scenarios
	6. Generation of a table board for following the development of related immaterial capitals
End of October 2013	7. Deployment of the suitable roadmap and the table board of immaterial capitals
From October 2013 to Jun 2014	8. Following and observation of the development of the project
Jun 2014	9. The summary at the end of design
201X	10. The final summary after the commerce of collection

Table 13-3: Timeline of the experiment of "Vertebral Column model" into Quiksilver

For finalizing the project, several results will be measured in the medium term (end of product development for summer 2014) and others will be observed only after the commerce of the collection. But the objective of this experiment in this thesis is to validate the usability of the "Tactic module" which supports the company to construct the tactic roadmap with several suitable operational scenarios. The governance and the final modification of corporate immaterial capitals are not included into this chapter. So the next paragraphs only present action 4 to action 7.

The strategic module supports the company to identify the corporate environmental objectives. These objectives and the context analysis of Quiksilver are considered as two main inputs to launch the "Tactic module". The next figure 13-5 shows the working process of "Tactic module" in Quiksilver.

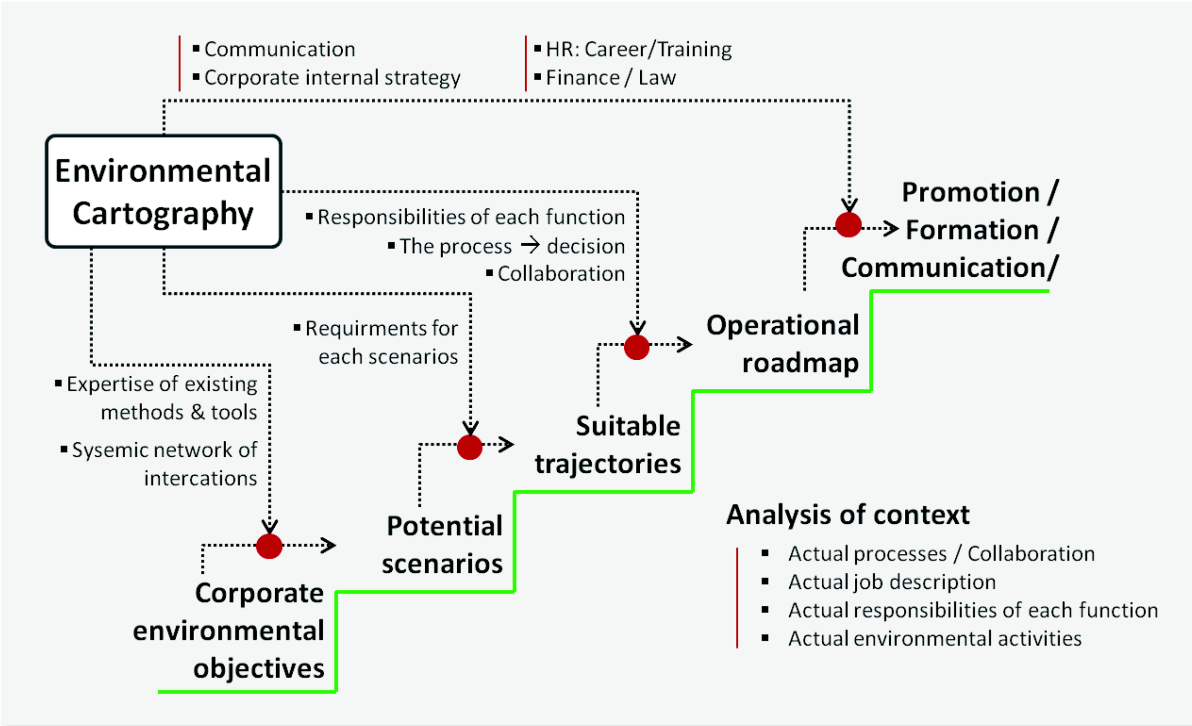


Figure 13-5: The working process of “Tactic module” for the experiment into Quiksilver

Firstly, depending on the selected “corporate environmental objectives”, the “module tactic” identifies the targeted actions into environmental cartography. These targeted actions initial the inverse generation of the theoretical scenarios to realize thus objectives (named as the “potential scenarios” map as below). Next, according to the corporate preference and the context, the “tactic module” proposes several prioritized scenarios and collaborates with the company to define a “suitable trajectory”. Then, with the support of the environmental cartography, the “operational roadmap” is realized including the detailed definition about the working process and the responsibilities of each related function. Finally, some transversal supports, such as the training, external promotion and internal communication are defined to ensure the operation of program.

13.4 Tactic module to support the generation of prioritized scenarios according to corporate preference

The strategic module of Convergence project supported Quiksilver to evaluate the actual maturity profile of the corporate governance. It also analyzed the potential improvements about the immaterial capitals at corporate level and some potential tendency of sustainable development which might support thus improvements. According to these results, the strategic module proposed a set of possible “strategic objectives”. Finally, after the discussion among the corporate chief operational officer, the director of R&D department, the specialist of textile innovation and our “convergence team”, the global tendency for corporate sustainable development is to **control environmental costs and to look for some opportunities to reduce costs related to the environment**. In order to ensure the achievement, two environmental objectives have been fixed:

- **Optimization of the material utilization into the product and service**
- **Augmentation of the product’s recycling or recyclability**

As a branch of global management committee, the division “Quiksilver Europe” hasn’t the directly power to affect the global corporate strategy without the proof of benefits. So firstly, in order to initiate the environmental program and to look forward some positive feedback, Quiksilver decided to implement these two environmental objectives for a whole collection (Autumn/Winner collection for a year).

13.4.1 Exploration of all potential trajectories for answering these two objectives

We are facing the treatment of two environmental objectives at the same time. In order to generate a complex network of potential actions and explore the trajectories, it’s necessary to find out and match a sub-list of pre-fixed environmental targets into the cartography for these two environmental objectives of Quiksilver.

The first objective concerns the optimization of material use of the whole product’s life cycle. Additionally, the company requires an improvement of results more justified and correct. So “a life cycle assessment with the process for optimizing some significant environmental impacts” is a correct selection.

The second objective “Augmentation of the product’s recycling or recyclability” requires two possibilities: either the company optimizes the real recycling of these products (such as the participation into the improvement of the collection and recycling process, the recuperation of recycled materials into the real product supply flow, etc.), or the company optimizes the design of product in order to augment the recyclability. So according to these two possibilities, two pre-fixed environmental objectives into cartography have been selected: 1) the recycled material acquisition management; and 2) the design for recyclability.

According to the “action network of environmental cartography”, a “Scenarios map” to resolve these two corporate environmental objectives have been realized as blew:

In the environmental cartography, the first environmental objective is considered as an environmental target: "product-oriented life cycles environmental performance improvement (only focuses on the material utilization)". So for hitting this objective, the final attended action (a start point of exploration) is the "Action 11.2 Calculation of improved product's life cycle environmental performances". So following the relationship of the interactions, the explorer finds out two branches for preparing a required action "9.2 Alternative eco-design / process improvement". This alternative design of product focusing on the whole life cycle performance could either refer to the LCA evaluation of actual product (Action 8.3 Identification of product environmental improvement specification), or refer to the improvement and contribution from the supplier (Action 11.4 Final supply contract). These two branches will be presented into next figure 13-6 as two principal scenarios: the "Optimization of product by the consideration of LCA" and the "Optimization of product by the contribution of suppliers".

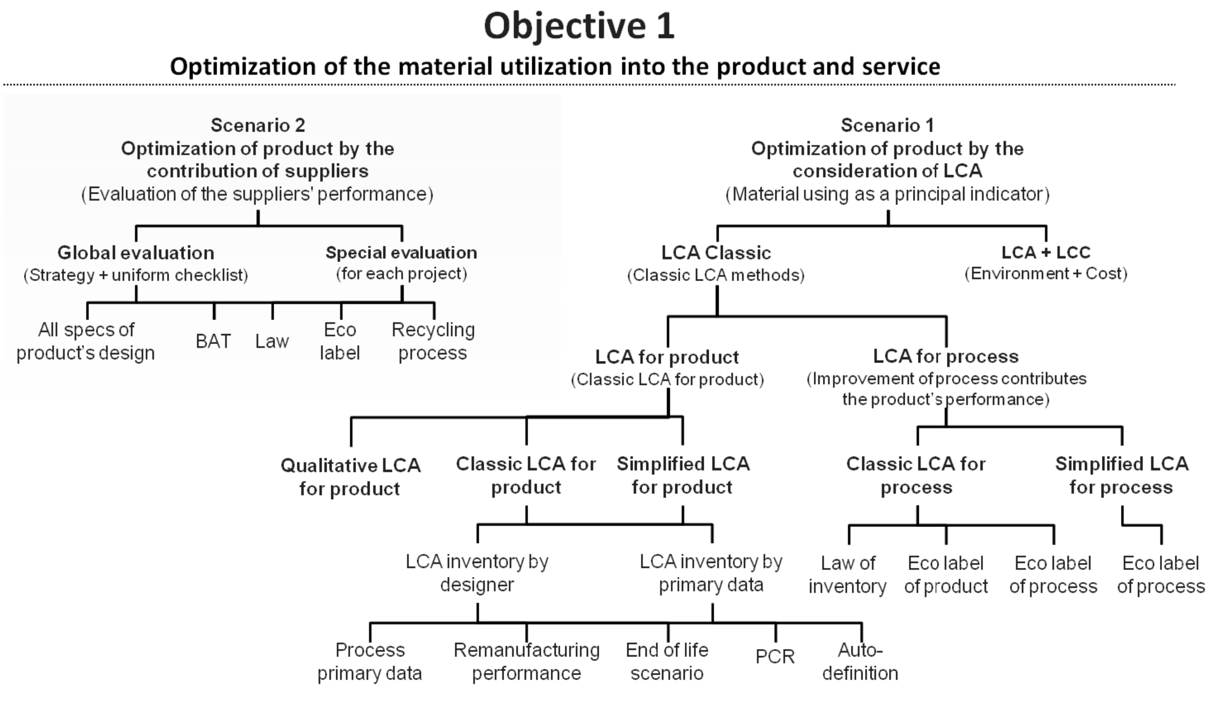


Figure 13-6: Scenarios map of the objective 1 (of the case study in Quiksilver): Optimization of the material utilization into the product and service

This scenarios map summaries several potential trajectories to resolve the first objective: Optimization of the material utilization into the product and service. The scenario 1 presents the classic solutions that optimize the product's performances by the eco-design. The classic approach about the LCA is a basic choice. But, the economical profits (the Life cycle cost (LCC) analysis) of each environmental improvement could be considered and integrated to make the balance between the technical and economic aspects. Meanwhile, the improvement of product's life cycle performance could be oriented by the needs from either the product itself or the manufacturing site's environmental protection[50]. So there are two branches below the "LCA classic", the "classic LCA for product" and the "classic LCA for process". Certainly, for each LCA, two principal approaches could be used: the completed version and the simplified version. In this case, the simplified version means that this life cycle analysis only focuses on one environmental aspect: "material utilization". Then, in order to prepare the environmental inventory, beside of the classic solution, "LCA inventory by the definition of designer", the primary data from the factory (the real material flow, the real logistic and stock data, the real production data, etc.) could be used to increase the creditability of the calculation. Finally, the criteria of eco labels, the product-category rules of LCA and the environmental laws could be considered as the reference for identifying the LCA analysis scope and the related functional unit.

Meanwhile, beside of classic scenario 1, the second scenario 2 provides a simpler solution to treat the same objective. Here, the company doesn't need to realize any improvements, but all environmental works are required to be achieved by the suppliers. Depending on the corporate needs, the company identifies the contents of checklist to evaluate if the suppliers have realized thus improvements. With the proofs from the suppliers, the company might communicate its achievements. Generally, this scenario includes two principal approaches: either the company identifies a common environmental checklist for all suppliers, or the company identifies some particular checklist for each product's category. Equally, some existing environmental data could be considered as the references to establish these checklists, such as the existing "Best Available Technologies", the "criteria of eco labels", the "specification of potential eco-design" and especially, the "material recycling process".

Following the same conception, in order to resolve second objective "Augmentation of the product's recycling or recyclability", it's necessary to firstly identify a start point to launch the exploration. Based on the requirements of this objective, we suggest that the action "11.1 Calculation of improved product's recyclability" is a right action to answer all needs. In order to calculate this rate, the new product's end of life treatment scenarios needs to be identified (the action "10.1 Identification of improved product-component's end of life treatment

[50] In order to answer the needs to ISO 14001 compliance, the company launches an environmental review of all manufacturing processes into a factory. The results might indicate that the significant environmental impacts of this factory come from a particular production line (of certain product). So in order to optimize the factory's environmental performance, the product's redesign might be a solution to avoid the significant manufacturing impacts.

scenarios”). And there are three different branches to support this identification: the supplier’s improvement from “Action 11.4 Final supply contract”, the collaboration with recyclers (from Action 11.6 Identification of improved collecting and end of life treatment manner) and the product’s optimization by designer (from Action 9.1 Alternative product recycling/assembly performance improvement). These three branches are presented as three different scenarios in next figure 13-7.

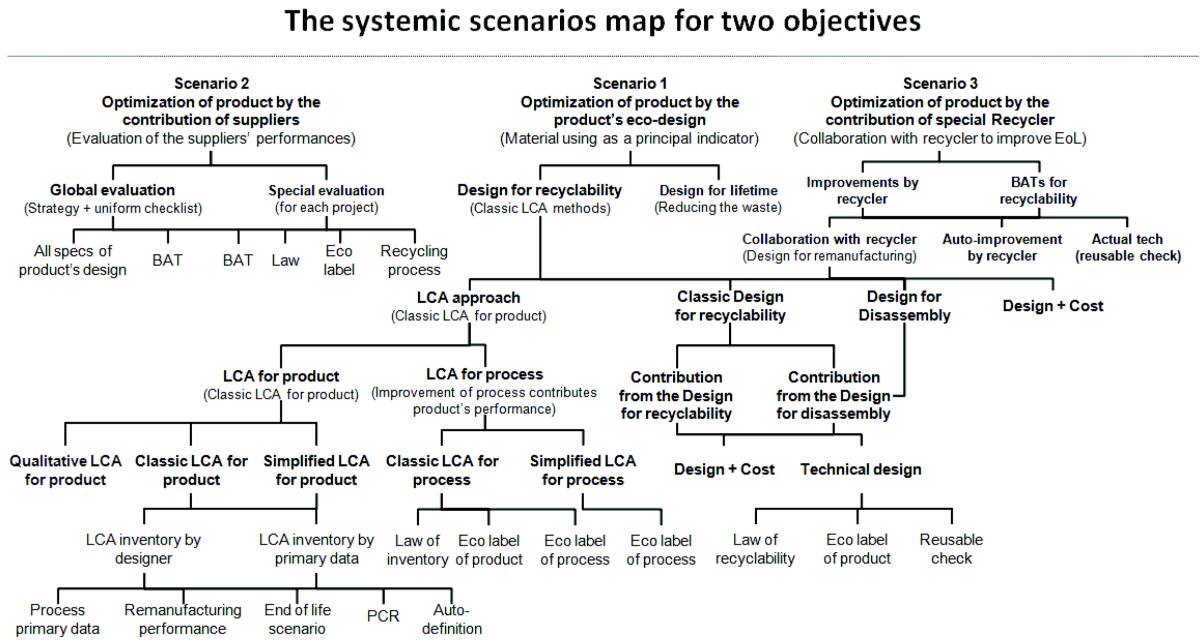


Figure 13-7: Scenarios map of the objective 2 (of the case study in Quiksilver): Augmentation of the product’s recycling or recyclability

Similarly with the previous objective, the suppliers’ evaluation could indirectly support the achievement of all requirements. This scenario means that the suppliers augment the recyclability of its components and the company might profit them to communicate the product’s improvement.

Meanwhile, the classic solution of this objective, presented as “scenario 1” in above map, is the “eco-design for optimizing the product’s recyclability”. Certainly, the “design for prolonging the product’s lifetime” might be an option (the prolonging of the lifetime generates the reduction of waste volume. This reduction could be considered as an indirect solution to augment the recyclability). In order to launch the “design for recyclability”, four different options could be selected: Firstly, the results of LCA evaluation could be directly used to set up the specification (the sub-branches of this option have been presented into above objective). Meanwhile, there are special methods, “design for recyclability” and the “design for disassembly” that could be also used. In order to identify the targeted recycling components, the reusable check (which includes the technical consideration and the marketing consideration), the criteria of eco labels and the requirements from the directive (ex: WEEE disassembly list) might be referred. Lastly, the economic aspects might be integrated to complete the eco-design (presented as "Design + Cost" in above figure).

The third scenario of this objective is to collaborate with the recycler to optimize the recyclability. Based on the treatment contract of the waste, the company could directly profit the achievements of recyclers to communicate its performance. Meanwhile, in order to further optimize the recycling process of its products, the company might require the implementation of "BATs" for recycling process or re-design the product to optimize the treatment process. The methods to make the collaboration are same with the scenario 1.

Now, Quiksilver needs to resolve these two objectives at the same times. According to the above descriptions for each objective, several common trajectories might be used. Finally, a systemic scenarios map has been proposed which includes all potential trajectories for two objectives.

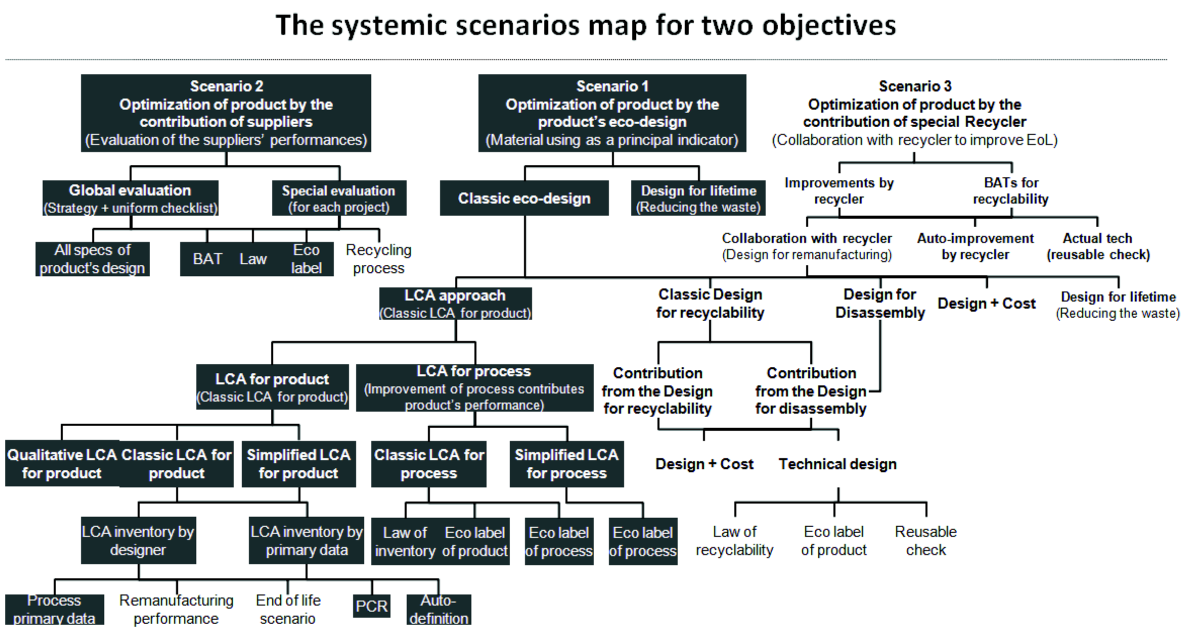


Figure 13-8: Scenarios map of two objective (of the case study in Quiksilver)
The actions within black background: the sharable trajectories for two objectives
The other actions: the special trajectories only for objective 2

The "material utilization" and the "recyclability" might be considered as two indicators of the product's environmental profits. So these two indicators could be focused on into the product's LCA approach and the checklist for evaluating the suppliers. So these two scenarios, noticed in black, are considered as the common trajectories for two objectives.

13.4.2 Analysis about the current knowledge and implemented actions into Quiksilver

The above section 13.4.1 summarized vast numbers of potential solutions to treat two pre-defined environmental objectives. Meanwhile, depending on the environmental information registered into the environmental cartography, the list of required environmental data and the related knowledge has been realized. So this section is to analyze the actual situation about these required knowledge and data into Quiksilver. This analysis will support the selection of the suitable trajectories according to the "operational preference".

The next table summarizes the implemented environmental projects into Quiksilver and the list of selected methods.

Project topics	Methods	Perimeter	Results
Bio Cotton	GOTS certification of suppliers	All products	35% of products
Global performance	OEKO-100 certification of suppliers	All products	100% of products
Supplier management	QUEST Checklist	All suppliers	100% of suppliers
Eco circle - material	Checklist of materials (Black, gray and white list)	1 product	realized
Eco circle - LCA	Simplified LCA	1 product	realized
Eco circle - Recycling	Checklist of suppliers	1 supplier	realized

Table 13-4: The implemented environmental projects into Quiksilver

From this table, it's indicated that Quiksilver successfully realizes the supplier's evaluation to answer the environmental requirements. The corporate common checklist "QUEST" is well known by the suppliers (100% of suppliers have been certified). Meanwhile, the requirements from two additional certification systems have been also diffused to the suppliers. So here, in order to realize all different trajectories of scenario 1, Quiksilver don't need to develop the new knowledge and the working process. The preparatory of the new requirements from the BATs and other eco labels, and the update of the "QUEST" checklist are considered as two principal actions to be realized.

Facing the scenario 2, the "optimization of product by realizing the eco-design", Quicksilver only realized a particular project only for 1 product. Meanwhile, the working process of LCA and the establishment of material authorization list are charged by external environmental consultation. So this time, in order to launch the project for a whole collection, a depth preparatory study is required to develop or integrate the expertise of LCA, establish the operational methods and tools to support the working process and develop the environmental database to register the results. Meanwhile, it's necessary to mention that Quiksilver should ask its supplier to prepare the environmental inventory of LCA, due to the fact that it doesn't charge the production phase. But a large number of its suppliers are small size company in Asia. Because of the lack of local legal requirements and the poor knowledge about environmental consideration, it's not simple to ensure the availability and the quality of environmental data.

Beside of LCA, Quiksilver hasn't the experiences about all special methods about "recyclability" and the manner about the collaboration with recycler. If some actions will be selected, all required actions and related knowledge are necessary to be developed. The existing relationship with the external experts could certainly support these needs.

13.4.3 "Operational preference" of the selection

In order to define the "operational preference", a meeting involving multiple stakeholders has been organized to discuss the real company needs and the operational constraints. Finally, the corporate chief operational officer, the design director, the expert of textile innovation and the partners of project convergence have participated to this meeting and summarized the actual corporate operational constraints. An external environmental expert has been invited to complete his comments:

- The timing pressure of product R&D: the R&D process of 20XX collection has been launched and this design session should finish in six months. So completely, there are only five months to complete all works which includes the preparatory studies, the specification of environmental improvement, the alternative design and the evaluation and collaboration with the suppliers to ensure the deliverability.
- The collection of all necessary data is very difficult for realizing the life cycle analysis, even for a streamlined version. As mentioned into above section, many suppliers are situated in Asia, especially in China, and in some Southeast Asia countries. Because of the different legislation background and the limit of technical capacities, the detailed environmental data about the whole production process sometimes is not available. Additionally, the timing pressure doesn't allow a long term negotiation to collect the data.
- The company is facing the organizational change. The responsibilities of each function might be modified to adapt the new organization structure.

- The European division respects the collection design. But the sourcing department which charge the relationship with suppliers, need to consider the global corporate strategies (including the America division and Australia division). Additionally, by considering the timing pressure, a large-scale update of environmental checklist is not available.
- The materials into “REACH SVHC list” have been analyzed by an independent laboratory. The requirements about these materials have been integrated into the mandatory corporate quality checklist for evaluating the suppliers. Several suppliers have been certified by the environmental labelling system, such as 30% of suppliers are certified by GOTS label and 100% of suppliers are certified by TEKO-100 standard. In order to receive these two above certifications, the environmental management system and the BAT must be integrated into the supplier’s entity.
- An external environmental expert (external consulting source) is prepared to support all type of environmental needs. He has competences about all types of LCA, design for recyclability and preparation of checklist.

According to these constraints, finally, the “operational preference” has been fixed as: Under the premise of environmental justification, **the environmental trajectories should be simple enough and they could be quickly and easily integrated into the corporate process.**

13.4.4 Four prioritized trajectories for fitting the operational preference

Depending on the “operational preference”, some operational characteristics of each potential trajectory have been analyzed, such as the list of necessary competences, the total duration and the related operational cost. In order to simplify the presentation to the corporate CCO and to highlight the prioritized solutions, four different trajectories were pre-selected. These trajectories regroup multiple actions to resolve two environmental objectives. The first two trajectories focus on the operational simplicity and provide the first stage of environmental consideration for whole collection. The third and fourth trajectories suggest some improvement for products themselves. These suggestions ensure the operational flexibility (decoupling the success of environmental program with the availability of external resource) and provide some environmental data for next stage.

13.4.4.1 Trajectory 1 - without any re-design + basic certification of supplier

According to the operational preference, the environmental trajectories should be simple to be integrated. Facing the achieved projects of Quiksilver, especially, the successful implementation of “QUEST” checklist for each supplier, a first scenario was proposed. The basic conception of this trajectory is without any requirements about product re-design and to ask the basic certification and proofs of environmental performance of suppliers. For recycling aspect, company requires the suppliers providing the proofs about the integration of recycled material and profits of this result to present the product's recycling performance.

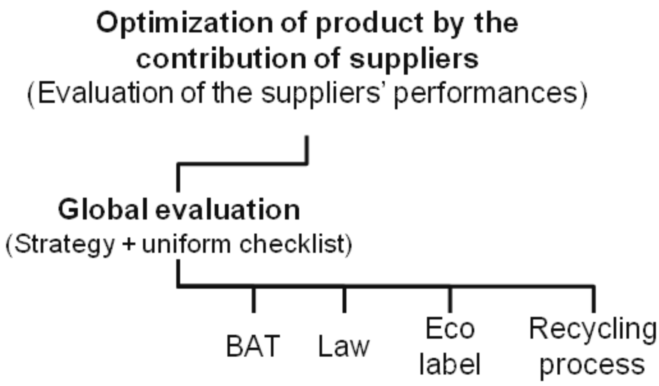


Figure 13-9: The trajectory 1 fits the operational preference

The principal proposition is to "optimize the product by the contribution of suppliers". In order to simplify the working process, at the collection level, the company is required to set up a common private definition about "Green Product". This definition is to answer the option into the above scenario map: "Global evaluation (strategy + uniform checklist)" The criteria of this definition are referred from the environmental laws and the certification of environmental management system (EMS), the criteria of eco label, the proofs of the implementation of BAT and especially for objective 2, the proof of recycling process. As mentioned earlier, the checklist of REACH directive, the requirement of EMA and BAT implementation have been realized. The workload might focus on 1) Do the existing criteria of other eco labels might contribute to this checklist? 2) The manner to ask the proofs of the utilization of recycled materials and 3) the formula and method to regroup these requirements to set up a common checklist.

This proposed trajectory might directly use the existing working process. Without any requirements of product's re-design, this scenario is simple and it can be quickly and easily integrated into the company. Meanwhile, this scenario contributes also the competence to answer a new topic by reorganizing some existing information.

But, facing this potential trajectory, only implementing this trajectory should face an operational risk: the availability of suitable suppliers which could answer the environmental attends, and also the normal economic attends. So, if this scenario has been selected, it's necessary to announce this new environmental constraint to sourcing department to pre-analyze the state, and the contents of final checklist need to consider the feedback from this preparatory analysis.

13.4.4.2 A simplest trajectory 2 – Integration of existing environmental analysis results

The basic conception of this second trajectory is similar with the first. The principal work also selects the "optimization of product by the contribution of suppliers". Meanwhile, this trajectory doesn't also require any re-design of product and it asks the supplier to achieve the improvement.

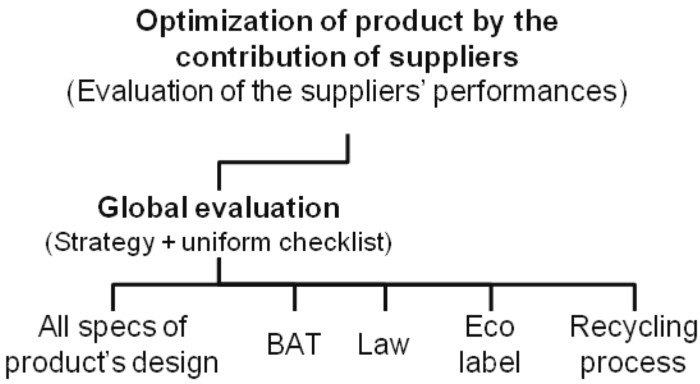


Figure 13-10: The scenario 2 fits the operational preference

The difference between the two trajectories is that the integration of existing environmental evaluation of actual product into the establishment of checklist. The trajectory 1 only focuses on the external requirements and standards. But this trajectory suggests the company involve the results of actual environmental projects to set the criteria which exactly hit the impacts of Quiksilver's product. Although the "Eco circle" only realizes a streamlined LCA for a product, the experience of certain textile's characteristics, such as the materials, the connecting technologies and the impacts about the colors and dyeing tooling, could be directly referred to other textile product. Meanwhile, these two actual proposed trajectories don't require eco-design for the product. This integration of these achievements prepares some experiences about how to successfully require the new performances of suppliers according to the requirement of further eco-design (such as the working process to update the checklist, the manner to contact and require the suppliers, etc.). The potential risk is also the availability of suitable suppliers. The pre-analysis by sourcing department is necessary to evaluate the possibility of implementation.

13.4.4.3 A mixed trajectory 3 – considering the re-design for improving recyclability

The success of the two above trajectories depends on the availability of the suitable supplier to provide the product with recycled material. This limit affects the operational flexibility of environmental program. In order to avoid the risk, in parallel, the Quiksilver launches also some product eco-design to ensure the final achievements. Due to the limit of available environmental data, this trajectory suggests the company to launch the re-design process to optimize the product's recyclability by the "DfR (design for recyclability) approach".

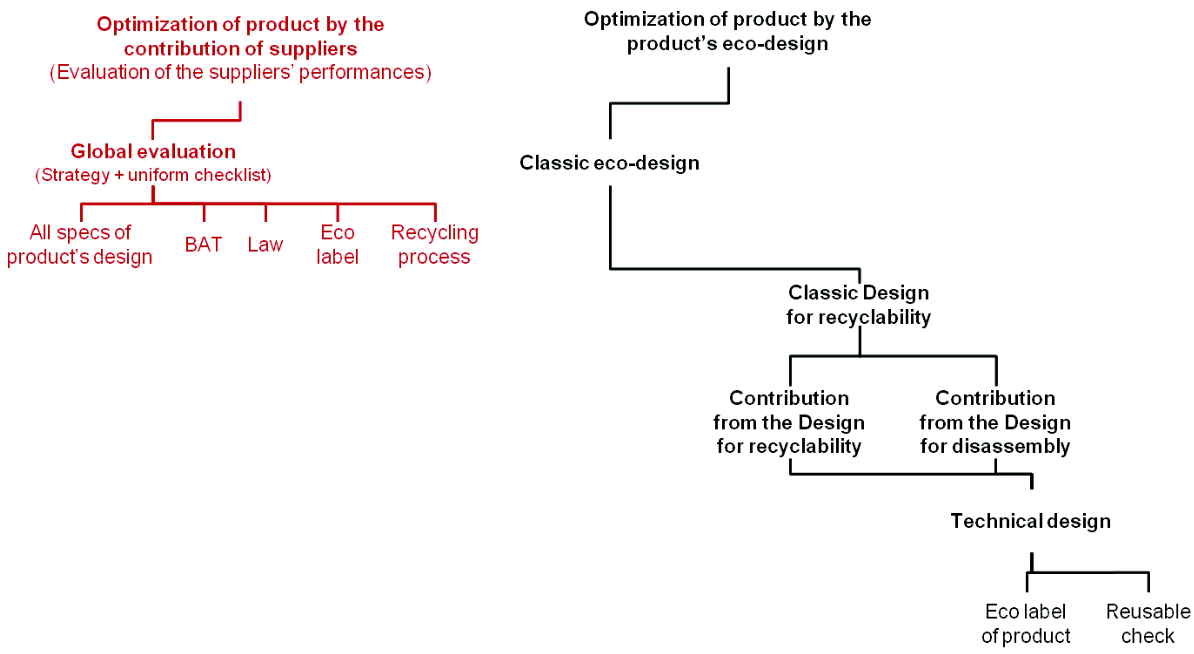


Figure 13-11: The mixed trajectory 3 fits the operational preference

In order to launch the DfR approach, some preparatory studies are necessary to be realized which include the definition of referential product, the method of evaluation, and the guideline of the improvement. Meanwhile, some industrial success stories and an internal brainstorming need to be organized to generate the design ideas. All types of above technical supports can be supported by the methods and tools registered into the environmental cartography (the details indicated into the section below).

13.4.4.4 A complete trajectory 4 – considering the whole life cycle environmental impacts

According to the "operational preference", the last proposed trajectory is a most complete version. Beside of the "DfR approach", the R&D team and the external expert also launch a LCA to consider the environmental performance of whole life cycle. Considering the limit of environmental data and the timing pressure, the simplest version, qualitative LCA of textile product has been proposed.

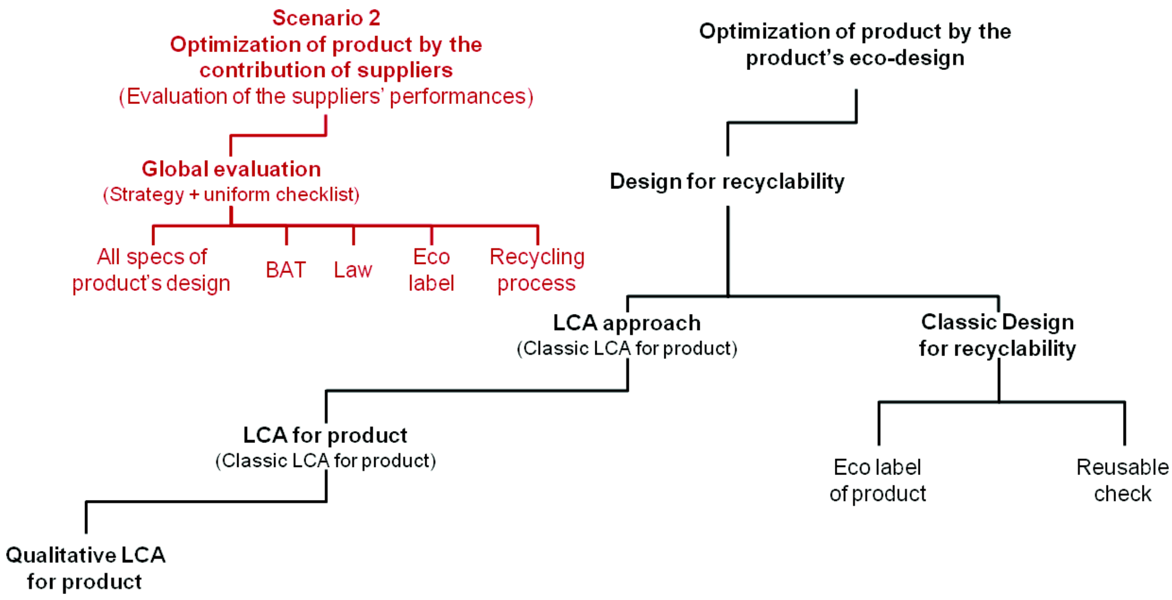


Figure 13-12: The complete trajectory 4 fits the operational preference

The benefits of this trajectory is that, firstly, the qualitative LCA provides a more rigorous and reliable result by considering multi-criteria; and secondly, these complete evaluation results (not limit on material using and recyclability) might profit the next environmental programs.

13.5 Mapping final selected trajectory to be implemented

The complete map of potential trajectories and four propositions have been presented to Quiksilver in order to define a final trajectory to be implemented.

After the discussion with external environmental expert to ensure the availability of resources and competences, company is interested in "trajectory 4" which provides a more reliable result and some possibilities of the future environmental program. This decision is approved by the corporate chief operational officer and the R&D director.

It's necessary to mention that these above four scenarios are only the proposition from the convergence partner who independently analyze the availability of the resources and the operational preference. But these propositions don't limit the corporate selection of other possibilities. Indeed with the help of the complete scenarios map, the company is authorized to select others depending on the resources development. In fact, beside of these trajectories proposed, the R&D team is also interested in the "collaboration with recyclers to improve the recyclability". During the meeting, the R&D director and our "convergence" team identify that the association “Emmaus[51]” could be considered as a collector of the used textile in the end of life. And this association is a great channel to prolong the lifetime or create the second lifetime of a used product. The R&D team would like to improve the product to fit the real needs of this association for prolonging the lifetime of principal components.

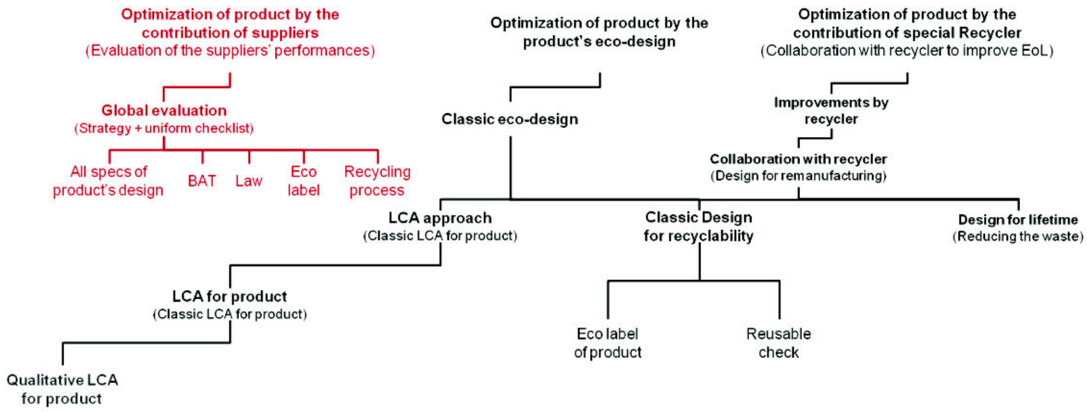


Figure 13-13: Final selected trajectories (proposed “trajectory 4” + Design for lifetime)

So, finally, the final operational scenario has been fixed which includes 4 topics. Meanwhile, the vast numbers of methods and tools registered into the environmental cartography are explored to support the implementation of each topic.

- **Topic 1:** Checklist to evaluate the suppliers to ensure the material utilization and the recyclability aspects during the manufacturing process. As the definition, the criteria of existing eco label systems, the laws and the BATs list will be considered as the references to update the existing “QUEST” checklist. So a depth analysis about the 84 eco label systems and a summary list of BATs are diffused to company. The details refer the above sections and the Annex (section of “eco label” and “BAT”).
- **Topic 2:** Collaboration with association “Emmaus” to prolong the lifetime and simplify the collection
- **Topic 3:** Design for improving the product’s recyclability. This product improvement needs to consider both the requirements of product’s design and the needs from the association of “Emmaus”. A list of available tools is offered to the company.

[51]Emmaus (French: Emmaüs) is an international charitable movement founded in Paris in 1949 by the Catholic priest Abbé Pierre to combat poverty and homelessness. This association collects some used daily supplies, such as the clothes, the furniture, the books, the domestic machine, etc. These collected used goods will be diffused or resold to poverty with a low-price.

- **Topic 4:** Qualitative LCA to measure the whole life cycle environmental impacts. Several available methods are proposed, such as the “ERPA” matrix, the “MECO” matrix, the “MET” matrix and some other references about the product-oriented life cycle checklist. The details refer the Annex (section of “product-oriented LCA by matrix” and “product-oriented checklist”).

According to the selected topics, the detailed environmental action network has been realized as below (Figure 13-14). Meanwhile the interactions between different topics and the decisional flow of collaboration have been presented to make a systemic and holistic view of the environmental program.

There, four different topics need to be implemented at same time, so the harmonization of these topics is a significant issue. Beside of the result of classic “Design for Recyclability” method, the R&D team realizes that the re-design should consider also the answer of the supplier’s evaluation and the real needs from the used product collector – the association of Emmaus. The combination and the harmonization of these three contents are considered as a completed specification of new product development. Meanwhile, the impacts of these modifications on LCA analysis results is an additional issue that need to be involved into the final decision. Then, at the end of the project, the improvement which generated from the controlling of suppliers (the comparison between the actual in-evaluated suppliers and new evaluated suppliers) need to be integrated into the final calculation of product’s recyclability, as well as the LCA results.

The company can further consider the LCA results of actual product into the checklist to complete the checklist. Although this option is not predefined by the company, if the external suitable supplier is prepared, the channel of informational exchange between these two topics is always available.

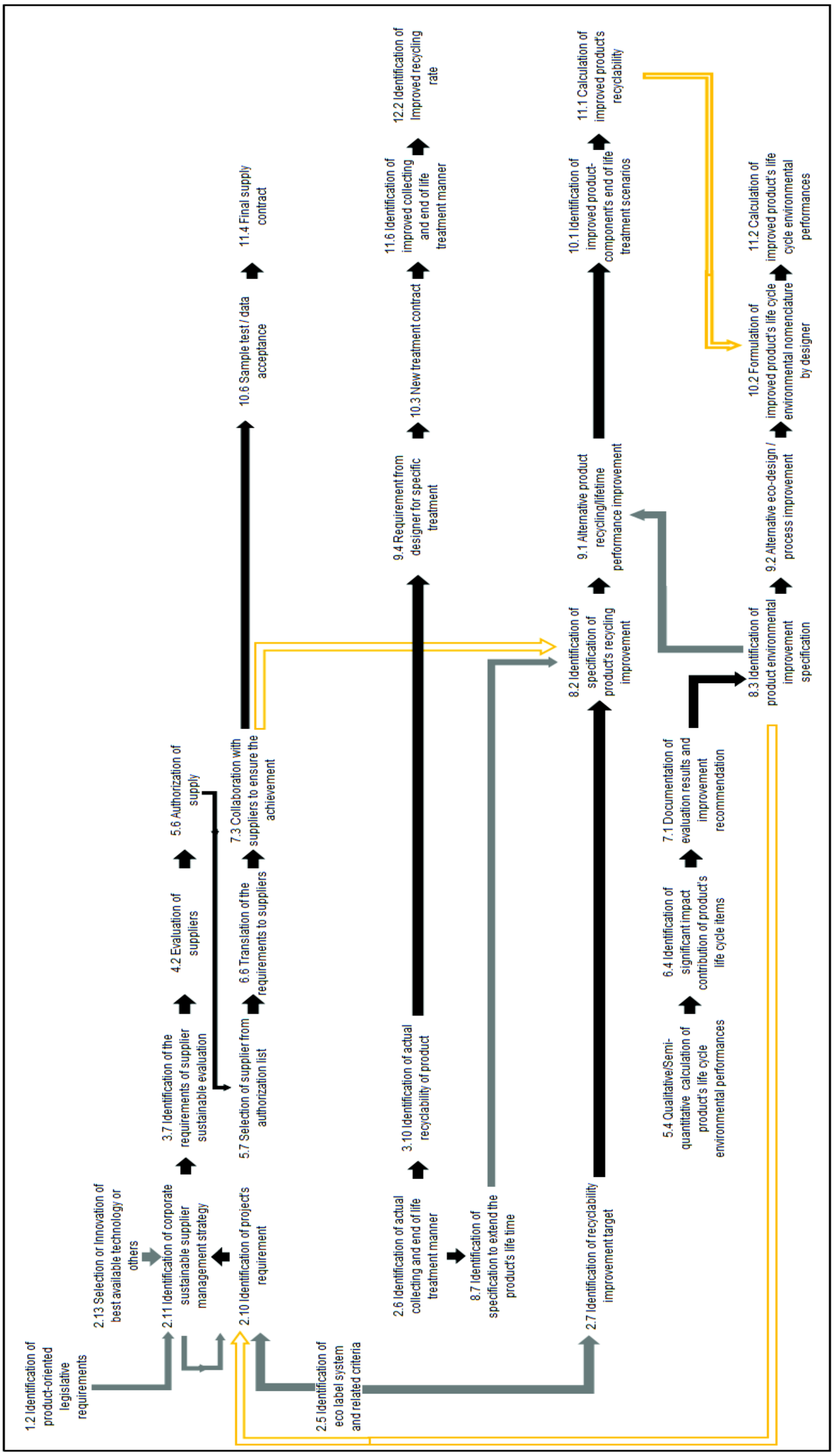


Figure 13-14: The detailed environmental actions network for selected scenario

The action chain and interactions are generated from "Environmental cartography"

Black arrow: presents the original Inheritance relationship between two different actions

Gray arrow: presents the interactions between different topics

Orange arrow: presents the "Contribution" interactions

13.6 "Tactic module" generates operational programming of the final selected scenario

The final selected trajectory summarized a set of actions and a standard working flow to resolve the environmental objectives. But this working flow is not in line with real corporate working process and collaboration flow. In order to integrate the required actions plan, it's necessary to designate the related responsibilities of each corporate function and map a working process to contribute to the environmental integration.

With the support from the detailed description about each required actions, a workshop was organized to finalize the process mapping. This workshop includes the company R&D director, an environmental expert and two PhD students from convergence project. During this workshop, the project presented the detailed requirements of each action, such as the purpose of this action, the necessary environmental data and knowledge to realize this action. According to actual working process, this workshop identifies the role, mission and responsibilities of each involved corporate function.

An example to realize the action "identification of eco label system and selection of related criteria" is presented here to demonstrate the definition. Firstly, the description about this action was explored from the environmental cartography.

Action: Identification of eco label system and related product's criteria

The main purpose of this action is to identify which eco label system will be used. According to the selected eco label system, the related judgment criteria of this product could be obtained. The analysis might include the influence on local market, the process of certification, the achievability of criteria and the fee. According to these analyses, the company might select the right system and criteria for the following actions.

Inputs/Outputs necessary for this action

Input	Output
Product category	Criteria of eco labelling
Product marketing geography	
Analysis of eco label	

TABLE: I/O LIST OF ACTION

The competence necessary

- ✓ The knowledge of product's category
- ✓ The knowledge of product marketing geography
- ✓ The knowledge of eco label (influence, fee, process of certification, etc.)

Table 13-5: The detailed description about the action: identification of eco label system and related product's criteria

Theoretically, this action requires the company to analyze and define which eco label system will be used. According to the description, the analysis might focus on the influence on local market, the process of certification, the achievability of criteria and the fee. In order to launch this analysis, it's necessary to identify the knowledge about the product and the eco label systems. The product design and marketing department have the complete information about the product, but the R&D director indicated that the company doesn't have enough knowledge about the eco label system and they don't have the time to collect them. But, the information registered into the environmental cartography provides a depth analysis of a large list of existing eco labels (84 systems have been analyzed). The analysis results include the license numbers of each system, the criteria of evaluation and some detailed information about the labelling process. This information can directly support the company to take the necessary knowledge about the eco label system. Meanwhile, according to the interactions noticed into the selected trajectory, the selected criteria of the eco labels will support two different needs; both the update of supplier's checklist and the identification of product recycling targets (some criteria of eco label require the special treatment about some component very high concern with environmental impacts, such as the structure of battery should be designed as dismountable before the recycling process. This information might guide the company to define its components list).

So finally, according to the actual definition of corporate functions, the workshop defined that this action will be realized by the Quality department and the product R&D and that the marketing department support some necessary information. The principal working content will focus on the technical criteria of eco labels and especially, the requirements about the recycling aspect. The actual report registered into the environmental cartography about the eco labels will be referred to make the selection of the suitable criteria which will contribute to the new checklist for suppliers and the identification of recycling targets.

Period	Functions	Responsibilities	Supports	Outputs
Action: Identification of eco label system and related product's criteria				
Preparatory	Quality + R&D + Marketing	Analyze and select a suitable criteria of eco label systems to update the checklist for suppliers and the targets of recycling aspect	Registered data into cartography (Analysis of eco labels)	Selected criteria

Table 13-6: The responsibilities and supports for action: identification of eco label system and related product's criteria

Similar with this action, the workshop clarifies the responsibilities and the necessary supports for each required action. Five corporate functions, the R&D team, the external environmental expert, the production department (including the sourcing office), the product quality team and the marketing/commerce team, are considered as participants. Whether the modification of product design or the supplier's evaluation, the R&D team participates in all activities of this green program and plays a central role of progressing. This team needs to collaborate with other four participants to ensure the program's operation. The next table 13-7 presents the responsibilities of each participant.

Period	Functions	Responsibilities	Supports	Outputs
Action: Identification of eco label system and related product's criteria				
Preparatory	Quality + R&D + Marketing	Analyze and select a suitable criteria of eco label systems to update the checklist for suppliers and the targets of recycling aspect	Registered data into cartography (Analysis of eco labels)	Selected criteria
Action: Identification of product-oriented legislative requirements & Selection or Innovation of best available technology				
Preparatory	Quality + R&D + Envi. expert	Analyze the IPPC directive and the available BATs. → Select the BATs to update the checklist	Registered data into cartography (Analysis of BAT)	Selected BAT
Action: Identification of actual collecting and end of life treatment manner				
Preparatory	R&D	Contact association Emmaus to know the actual situation about the collecting and treatment		Actual situation of collecting and treatment
Action: Identification of actual recyclability of product Identification of recyclability improvement targets				
Preparatory	R&D + Envi. expert	Evaluate the actual recyclability of product and identify the targets	- Tools registered into cartography - Results of "Eco circle project" - Emmaus situation	Recyclability + Targets
Action: Qualitative calculation of product's life cycle environmental performance Identification of significant impacts of product's life cycle items Documentation of evaluation results and improvement recommendation				
Preparatory	Envi. expert	Realize the qualitative LCA for actual products + documentation of evaluation results	Tools registered into cartography (List of Matrix LCA)	LCA results
Action: Identification of corporate sustainable supplier management strategy Identification of the requirements of supplier sustainable evaluation Evaluation of suppliers Authorization of supply				
Creation & Design	R&D + Quality + Direction	Update the checklist for suppliers Direction validates this update Quality team evaluate the suppliers and approve the authorization for supplying	Selected criteria, BATs and the results of "Eco circle project"	New checklist
Action: Identification of specification of product's recycling improvement Identification of specification of product's environmental improvement Identification of spec to extend the product's life time				
Creation & Design	R&D	According to all evaluations about actual product / process, R&D identifies the specification of product's eco-design	Guideline registered into cartography	Updated collection plan

Action: Requirement from designer for specific treatment				
Creation & Design	R&D	- Collaborate with Emmaus for new collecting system - New treatment manner to avoid the damage of the clothing		Updated manners and collect system
Action: Selection of supplier from authorization list Translation of requirements to suppliers				
Development of collection	Production Sourcing	According to new checklist, sourcing identifies a shortlist of prioritized suppliers	New checklist	Potential suppliers list
Action: Alternative product recycling/ lifetime improvement Alternative eco-design / process improvement				
Development of collection	R&D + Envi. expert Quality + Sourcing	According to new collection plan (product spec), R&D generates the new design; Environmental expert supports this process and evaluates the results by LCA; Quality and sourcing participate the new design to ensure the availability of suppliers	Selected tools of Matrix LCA & Design for recyclability Selected guidelines that are registered into cartography	New design
Action: Collaboration with suppliers to ensure the achievement Sample test/data acceptance				
Development of collection	R&D	Contact with supplier for technical details + evaluate the results	New checklist Product's specification Results of eco-design	New product
Action: New treatment contract with recycler Identification of improved collecting and end of life treatment manner				
Document	R&D + Direction	Define the new collaboration with Emmaus		New end of life collect and treatment
Action: Identification of improved recycling rate Identification of improved product-component's end of life treatment scenarios Calculation of improved product's recyclability Formulation of improved product's life cycle environmental nomenclature by designer Calculation of improved product's life cycle environmental performances				
Document	R&D	According to new product design and new end of life scenarios, R&D evaluates and calculates the achievements	Selected tools	The results of environmental improvements
Action: Final supply contract				
After R&D	Sourcing	Sign the supply contract		
Action: Marketing planning for environmental improvement				
After R&D	Marketing	Identify the marketing planning		

Table 13-7: Responsibilities and supports for all required actions (Case study of Quiksilver)

Environmental expert collaborates with R&D team for following four activities:

- During the "preparatory studies and research" step, environmental expert provides the matrix/checklist to R&D team for animating the qualitative LCA
- During the "preparatory studies and research" step, environmental expert provides the tools or checklist to R&D team for product's recyclability
- At the beginning of the "Creation & Design" step, environmental expert supports R&D team to complete of environmental checklist for supplier by the consideration of LCA results.
- During the steps of "Creation & Design" and "Development of collection", environmental expert follows the environmental improvement by using the LCA and DfR (identification of significant impacts and specification; supporting the idea generation of design and evaluating the environmental impacts of each modification)

Secondly, the quality team collaborates with R&D team for:

- During the "preparatory studies and research" step, quality team supports the R&D to set up a new environmental checklist by considering the existing "QUEST" checklist, the certification and the criteria of Ecolabel
- During the "Development of collection" step, quality team accompanies the process to supplier's evaluation with R&D team and production department.

Thirdly, the production department (including the sourcing office) is integrated into the program to:

- During the steps of "preparatory studies and research" and "Creation & Design", production team participates in the process of checklist establishment (with R&D and Quality team) in order to make the coherence between the environmental and financial performance.
- During the "Development of collection" step, according to the new requirements of environmental checklist, production team verifies and ensures the availability of suppliers (by the pre-evaluation and negotiation with main suppliers)

Fourthly, the marketing and commercial team participates in this program for:

- After the R&D, according to the new environmental features, marketing team collaborates with R&D team to set up the collated promotion planning.
- After the R&D, the commercial team reports the feedback about this collection to R&D and marketing team to pilot the potential modification of next environmental program in Quiksilver.

Finally, depending on the required actions and these above general definitions of responsibilities, a collaborative working process embedded into the normal corporate process has been defined as blow (Figure 13-15).

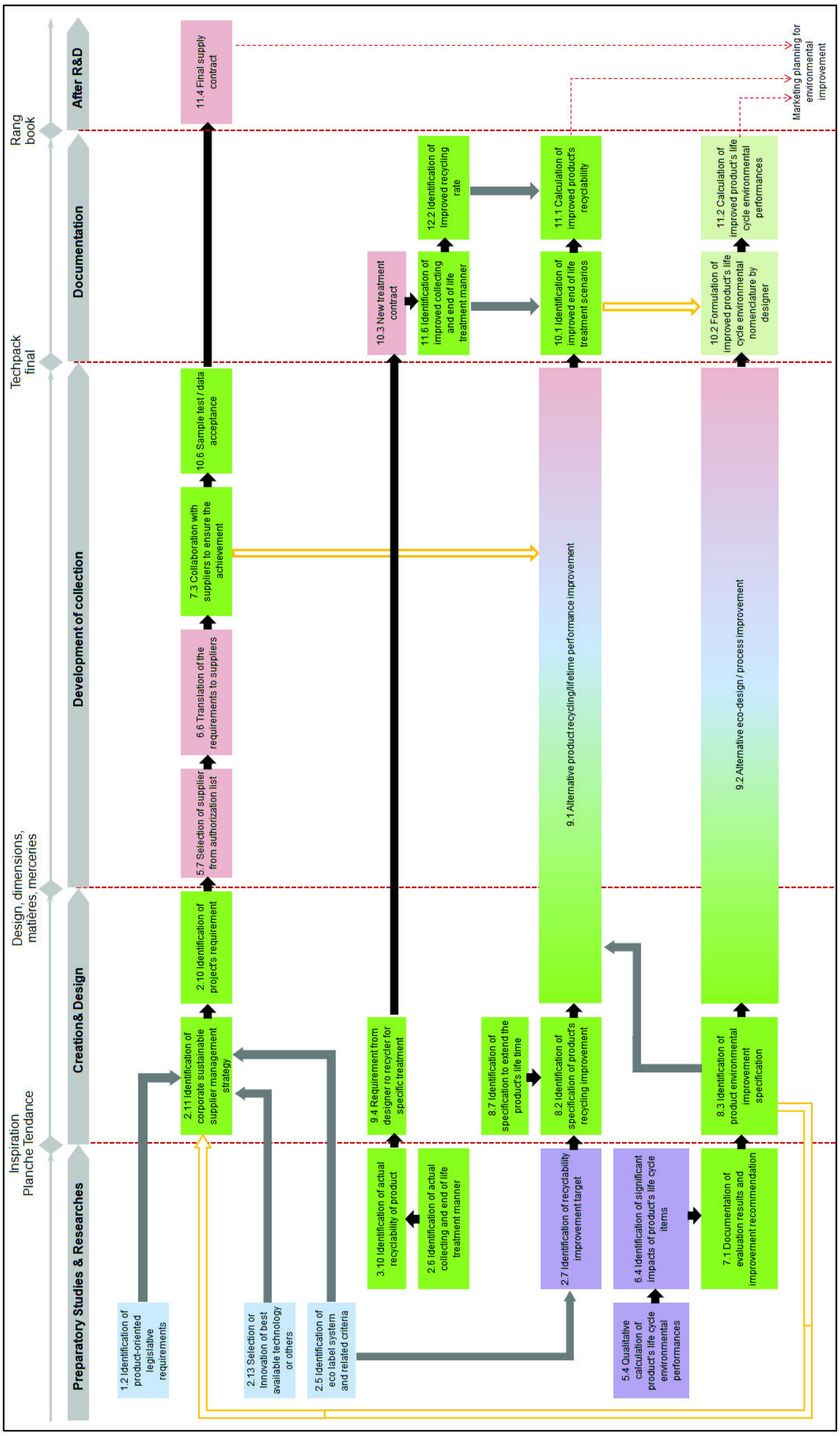


Figure 13-15: The working process for operating all required actions

Gray part: the normal corporate process

Green: the R&D team responses these actions Red: Production team responses these actions

Violet: Environmental expert responses these actions **Blue**: Quality team responses these actions

During the process of program mapping, the environmental cartography and the database provide two main supports to simplify the decision. Firstly, the relationship among different environmental actions provides a systemic view to map the detailed informational flow. When the workshop defines the detailed working content of an action, the relationship with others could indicate: 1) which outputs of other precedent actions need to be considered; 2) what activities should be done for affecting the decision of which following actions. Secondly, the registered expertise and environmental tools provides the necessary intelligent support about environmental knowledge. This information could directly simplify the preparatory studies for implementing the selected trajectory.

13.7 Building organizational support

In order to operate these required actions, beside of the preparatory studies of the related environmental requirements and methods, the training about the new environmental checklist, the new tools, such as the qualitative LCA and "Design for recyclability" and the new embedded process should be organized.

Form	Step	Topics	Organizer	Participant
Training	Preparatory studies & Researches	New environmental process	Program leader	All participants
	Preparatory studies & Researches	New design tools: - Qualitative LCA - Design for Recyclability	Environmental expert	R&D Team
	Creation & Design	Checklist for suppliers	R&D team	Quality team Production team
	Development of collection	Checklist for suppliers	Production team	Suppliers
Brainstorming	Creation & Design	Generation of new idea for eco-design	Environmental expert	R&D team

Table 13-8: The proposed organizational support for operating this environmental program

Meanwhile, following the actual habitude (implemented into "Eco circle") a brainstorming is necessary for generating new idea of eco-design.

13.8 Discussion and conclusion about the efficiency of "Tactic module" implemented into Quiksilver

In this thesis, we proposed that the "tactic module" and the "environmental cartography" could accelerate the environmental integration into the company. In order to validate this hypothesis, we measure the consistency of this module in the context of the Quiksilver's business through three steps of program planning: the generation of the possible operational trajectories; the selection of suitable trajectories to answer the predefined environmental objectives; and the operational design for integrating these environmental activities into actual working process.

Firstly, a survey about the industrial and corporate actual situation has been realized to understand the context for implementing the environmental program. As a large size company, the process of product R&D requires the collaboration of different functions, which includes the product's R&D team, the quality team, the production team, the marketing team and the external intelligent support (environmental expert).

13.8.1 The "Tactic Module" provides an efficient solution to explore a large number of possible trajectories for answering environmental objectives

Firstly, from the results of case studies into Quiksilver, we could demonstrate that this cartography and the "take-back" mechanism could efficiently generate several systemic trajectories to answer the environmental objectives. In this case, the details of 46 standard environmental approaches allow the generation of scenarios map in a short time (During this case studies, 1 completed working day is enough to generate the scenario maps and provide four prioritized scenarios). Finally, in order to answer 2 objectives, there are more than 10 environmental trajectories have been generated and each trajectory is considered as an independent solution which could completely replace others. The different operational trajectories require different chain of environmental actions, so the operational difficulties, the necessities (such as the required cost and time frame, the necessary competences etc), the related corporate functions and the manner of collaboration are various. In this case, three different types of life cycle analysis have been proposed. Beside of these completed tools, the design for recyclability, the collaboration with supplier, the checklist for evaluating the suppliers were proposed also to be selected. The company could select one or more suitable trajectories to resolve environmental objectives according to its corporate context and the real need of corporate development.

Meanwhile, the environmental cartography is constructed by 122 typical environmental actions from 20 topics of organization-oriented approaches and 26 of product-oriented approaches, so this systemic database ensure the proposed trajectories don't be limited into one approach. This systemic view of environmental solution enlarges the various possibilities of treatment. From this case, two product-oriented objectives need to be treated. The classic solution is to take the eco-design activities to realize these objectives. Beside of these classic solutions, these trajectories provide also some organization-oriented approaches to treat these product-oriented problems. In this case, for treating the second environmental objective, the improvement of product's recyclability, the results of exploration provides two different approaches; the first is based on the product level, the "Design for recyclability"; and the second is oriented from the organizational process which requires the collaboration with recycler to improve the treatment of waste flow. During the meeting with product's R&D director and other designers, this trajectory "collaboration with recycler" inspires the new idea to treat the recyclability, the collaboration with Emmaus and make some changes for adapting its collection process. So this result demonstrated that the environmental cartography allows different solution to treat a problem, allows different indicators to measure the environmental achievements and allows possibilities to use each corporate function, if necessary, to realize the environmental objective.

Thirdly, this case study explains how the "environmental cartography" and "take-back mechanism" find out the trajectories and regroups them as the common trajectory to treat two objectives. If the green supplier is available, the checklist for supplier, including different criteria about material using and recyclability topics, could directly treat two objectives. So the common processes of supplier evaluation ensure the sharability of environmental actions and reduce the necessity of operational resources. Meanwhile, LCA is a complete approach also to realize these two environmental indicators.

13.8.2 The "Tactic Module" provides an efficiency solution to prioritize the possible trajectories for multiple environmental objectives

In this case study, the "tactic module" prioritizes all explored trajectories according to the corporate preference. With the lack of environmental data and the time pressure, the company prefers the simplest and easiest trajectories to be implemented. The "tactic module" analyzed the details of corporate constraints and proposed four prioritized trajectories to company. The trajectory 1 has been proposed and requires product modification and asks only the certification of suppliers. Meanwhile, some easiest solutions of other approaches have been pointed out to complete the proposition, such as beside of the classic quantitative LCA, the selected trajectory follows the qualitative approach which requires less environmental data and is realized more easily.

Additionally, by analyzing these scenarios, the “tactic module” and the Quiksilver’s experts identify some operational risks of each scenario. This information completes the decisional support to company.

13.8.3 The “Tactic Module” provides an efficiency solution to establish the systemic operational planning to implement the required environmental actions into the normal working processes

The cartography is constructed with a series of environmental actions. So the trajectory doesn’t only provide macro solutions to treat the environmental objectives; it also breaks down the whole trajectory into a series of implementable actions. Thereby it thus dispersed the all operational necessities inside each node (means “action”) of trajectory. So the related corporate functions of each action need only to clearly understand the working details of this action and the interface with others. It’s not necessary to consider the details of other actions.

Meanwhile, in the scenarios map, there is a systemic relationship about the interactions of all relevant actions to treat two predefined environmental objectives. At micro level, it explains the working sequence and the collaborative relationship among different corporate functions by presenting the “interactions”. So according to real responsibilities of each corporate function, this systemic view about selected trajectories supports the program planner to easily clarify the environmental responsibilities of each relevant function and the working process in the context of multi-objectives. In this case, in order to prepare the checklist for evaluating the suppliers, the selected trajectory requires four different inputs: the legal requirements, the criteria of eco label, the BAT and the new requirements from the qualitative LCA analysis of actual product. So finally, matching the actual responsibilities, the planner could easily define that the R&D team is in charge of the integration of REACH evaluation into this new checklist, the external environmental experts and R&D team are in charge of the LCA analysis, etc. Further, the LCA analysis doesn’t only support the product’s design, but it also contributes to the definition of the checklist for suppliers. So, in the program planning, the environmental expert could be directly defined as the partner who needs to be integrated to answer two objectives.

13.8.4 The "Tactic Module" provides a perimeter to evaluate the operational risks of each proposition

The proposed tactic module provides a detailed mechanism to select the trajectory according to the analysis of available resources. During the decision about final suitable trajectory, we found that the operational risk is also an important indicator should be considered. Based on the corporate context, the simplest trajectory to answer the two objectives is the evaluation of suppliers. But the risk of available certificated supplier becomes a barrier for implementation. In order to avoid this risk, there are two backup solutions, the "design for recyclability" and "the qualitative LCA" are selected. Certainly, these selections might further optimize the environmental performances of product.

Although the proposed environmental cartography doesn't highlight the operational risks of each trajectory, it has integrated them as an input of operational resources. As look at this example, in order to implement the "action 4.2 evaluation of suppliers", the output of this action is the "shortlist of authorized suppliers". And this output is a mandatory input for next action. The risk of availability of suitable suppliers is transferred as the availability of this output. And it's based on the analysis of the availability of this output, we discovered this risk.

Meanwhile, facing the dynamic environmental objectives, we could not pre-define all risks without the generation of potential solutions. And the first step of risk analysis is always the list of all potential concerned issues. For example, the FMEA model (Failure mode and effects analysis) is a prioritize tools for quality problems. In order to analyze the quality problem, the first step is to list all quality related issues. The environmental cartography generates the list of potential scenarios for answering the objectives, which provides a perimeter to consider the potential risks.

In next research studies, we will try to highlight the operational risks for each trajectory and directly integrate the risk analysis into the mechanism of selection.

13.9 Conclusion of the efficiency of the "Tactic Module" through the Quiksilver case study

Depending on the environmental cartography and "tracking back" mechanism, this chapter presents how to support the company to pick out the right environmental trajectories in order to realize the predefined environmental objectives. During the three days into company, the results demonstrated that systemic cartography supports the efficient generation of several operational trajectories. Meanwhile, Depending on an in-depth analysis of environmental methods, the proposed trajectory could provide a systemic proposition which harmonize the product and site-oriented approach at “action” level. This result allows the company to use all potential corporate functions to improve the environmental performance and evaluate the environmental improvement by different indicators. The multi-proposition of potential trajectories allows the company prioritizing and selecting the most suitable operational solution according to its particular context. And the definition of the interactions among different environmental actions support also the efficient planning of the working processes and the responsibilities of each related functions.

Finally, in order to optimize the “Tactic module”, the risk analysis of each trajectory will be highlighted and directly integrated into the selection.

Chapter 14 - Experiment N°3 Deployment of the “Tactic module” into Festilight

This chapter is to present a second case study which integrates the proposition of “convergence” project into a small size company, Festilight. The company, Festilight only employs around 40 staffs. The section 14.1 provides a general description about the company, the environmental context in this domain and the actual environmental initiatives into this company. And then, the proposed environmental roadmaps will be presented into the section 14.2. In order to really initialize the environmental consideration about the aspect of recyclability, several scenarios maps have been proposed and prioritized. Meanwhile, the change of business model has been also considered into the proposition to try the balance of economic benefits and environmental improvement. The decision about the operational scenario will be presented into section 14.3. According to the selected scenario, the related operational planning is prepared into the section 14.4. And finally, the discussion and the conclusion of this experiment will be presented into paragraph 14.5.

14.1 Description of Festilight and its business

According to the official corporate website of Festilight, created 15 years ago, Festilight became one of the largest decorative and festive lighting companies in France and works on creative projects in more than a dozen countries. Based in Troyes city, the company employs 40 people and continues to grow to achieve sales of over EUR 9 million in 2011.

As a specialist of festival lighting and decoration, Festilight develops, manufactures and distributes light decoration for different types of final customers (B-to-C model): The professional annual requirements from the city hall, the communities or commercial centers and the special requirements for commercial or public events (the showcase of shopping mall, the commercial events and the solution for presenting the corporate marks). Certainly, Festilight faces a big volume of annual turnover form the B-to-B business model. The indirect customers includes the grand public distributors (Botanic, Jardiland or VillaVerde, etc.), some special commercial mall of decoration and some exporter.

14.1.1 Daily working process and the responsibilities of each corporate function

Although Festilight is a small size company, there are services of R&D, Marketing, commerce, production, supplier chain and Human Resource (HR) & Administration inside the company. And the service of HR is developing the detailed job description in order to normalize the daily contents of each position.

Firstly, the group president, the vice president and the commercial director present the strategic committee to identify the global tendency of business development. The manager of supply chain and HR are informed of all decisions.

All related services work together to make decision about product. Each year, R&D and commercial team visit the exposition of decoration product to collect the new design and related suppliers. Within these data, the commercial team directly contact final users (such as the city hall, the commercial center) to analyze the needs of decoration and prepare the planning. According to the planning and the installation environment, the R&D team validates if the requirements are achievable. If not, the commercial team reconnects the final users to finalize the modification. Then, the supply chain team alternatively contacts the suppliers to purchase all necessary components. At this moment, the Quality is involved into the purchasing process to validate and to provide the authorization of purchasing. Once all components arrive, the workers of production team assemble these components according to the decoration planning. And then, under the process of administration of commerce, the final products are delivered to the final installation place with a detailed installation guide (Realized by R&D team).

Figure 14-1: Festilight assembles the purchased components to design the decoration

It's necessary to highlight that Festilight is not in charge of the components design and production. All components are imported from the Asian suppliers. The role of R&D team on site is to define the achievability of assembly for all components. And the production team of Festilight has to define the process of assembly depending on the decoration plan.

Meanwhile, the R&D and quality team is very young. Starting from 2012, the first engineer of R&D team has been employed. Till today, there are 2 persons in this service (1 manager + 1 engineer) and the manager is only present 20% of its time for R&D activities. From 2013, there is an independent quality service which includes 1 person to evaluate the suppliers.

14.1.2 Environmental requirements for industry of decorative lighting

The industry of decorative and festive lighting could be considered as a sub-category of the industry of electric and electronic products. Because the production of all components is situated in Asia, the European directives about manufacturing process are not applied.

The first European environmental directive in this section is RoHS directive: Directive for Restriction of the use of the certain Hazardous Substances - 2002/95/EC. The objective is to limit the use of certain substances hazardous (First forbidden list includes 7 substances: mercury, cadmium, lead, Hexavalent chromium, PBB, PBDE and DecaBDE) in electrical and electronic equipment. The producer should declare a file with product in order to present the compliance. This directive fundamentally impacts the existing design.

The second environmental legislation of relevance for this sector is the REACH directive which requires the registration of all chemical substance, and the evaluation and restriction of the hazardous substance (SVHC – Substance Very High Concern). In this directive, all producers are considered as the downstream user of a wide variety of chemical products who must declare the weight or volumes of SVHCs contained and ensure a total responsibility in the management of such SVHCs according to security dash.

The third principal legislation is the WEEE directive (96/61/EC, directive for Waste of Electric and Electronic Equipment). Since August 2005, the waste of EE equipment covered by this directive must be separately collected and properly recycled in Europe. Depending on the requirements of the directive, the producer/importer must optimize and ensure the minimum recyclability of its product. Principally, there are three responsibilities: 1) the productor should be in charge of the "tack back" system of its waste; 2) the productor of lighting product should ensure that the recycling rate of its product is more than 50% and the valorization rate is up to 70%; and 3) the productor need to publish an end of life instruction to optimize the collection, the disassembly, the recycling and the treatment of its waste.

14.1.3 The environmental initiatives of Festilight

Festilight offers high performance products while taking into account economic, social and environmental stakes to enable the sustainable investments. Facing the legislative requirements, Festilight initiates several activities. In order to answer the RoHS directive, the forbidden list of hazardous substances has been completed involved into the checklist of suppliers. The suppliers should provide the certification of RoHS free which ensure the business with Festilight. Meanwhile, the compliance of REACH directive follows the same method. Beside of the proofs from suppliers, Festilight asks a test from a French independent laboratory to measure the content of SVHC substances. This double check ensures the veracity of results. For WEEE directive, Festilight participates into a common waste collection platform which ensures the company answers a part of legislative requirements. But Festilight hasn't measured the recyclability rate of its product and provided an instruction for optimizing the recyclability.

For some voluntary demarches, starting from 2004, Festilight uses the LED[52] technology in all new product developments and the professional range is 98% composed of LED products. Meanwhile, from 2011, Festilight cooperated with UTT (The Troyes University of Technology) to realize the "life cycle analysis" of their products.

14.2 New environmental objectives and related scenarios maps

From 2013, Festilight was trying to study the possibilities about the sustainable development. Festilight, aware of the "Convergence" project wanted to realize a systemic approach of environmental integration in the company, from the strategic decision to daily working process. So this second industrial case study has been organized to deploy the "Vertebral Column" model. As a part of this vertebral column, the tactic module has been integrated into this deployment to contribute to a systemic roadmap of environmental integration.

[52] A light-emitting diode (LED) is a semiconductor light source. LEDs are used as indicator lamps in many devices and are increasingly used for general lighting. The LED technology presents several environmental benefits: without mercury or produce any UV, the low energy consumption, the longer life time and the great recycling rate, etc.

14.2.1 Method of this experiment

Before this official launching, on 22 October 2013, a preparatory meeting between the strategic module and the president of company has been organized to identify the potential environmental objectives. Secondly, several interviews were organized during three days (from 29 to 31 October 2013). The “convergence” project team meted the key functions to construct corporate context about the responsibilities of each function, the daily work and related process. Three topics were addressed:

- State of the art about the current operational governance of the key activities (processes, tools and destination);
- Existence and nature of reporting to the strategic decision;
- The nature of relationships with external/internal partners contributing to the activities

Depending on this actual context, the “Vertebral Column model” has been implemented to identify the governance (Top-Down approach) following the next timeline:

22 October 2013	1. Identification of corporate business objectives 2. Definition of strategic objectives about environmental impacts
From 29 October to 31October 2013	3. Realization of maturity profile of corporate governance by the interviews with key functions (R&D, Quality, Marketing, Commerce, Supply chain and RH)
	4. Generation of the systemic tactic scenarios map to realize the strategic objectives
	5. Definition of a suitable roadmap by identifying the right scenarios
	6. Generation of a table board for following the development of related immaterial capitals
End of November 2013	7. Deployment of a suitable roadmap and table board of immaterial capitals
From December 2013 to April 2014	8. Following and observation of the development of project
April 2014	9. Summary at the end of design

Table 14-1: Timeline of the experiment of “Vertebral Column model” into Festilight

For finalizing the project, several results will be measured in the medium term (end of product development for summer 2014) and others will be observed only after the commerce of the collection. But the objective of this experiment in this thesis is to validate the efficiency of the “Tactic module” which supports the company to construct the tactic roadmap with several suitable operational scenarios. The governance and the final modification of corporate immaterial capitals are not included into this chapter. So the next paragraphs only present actions from action 4 to action 7.

Firstly, depending on the selected environmental objectives, the “tactic module” identifies the targeted actions into environmental cartography. These targeted actions imitate the inverse generation of the theoretic scenarios to realize thus objectives (named as scenarios map as below). Next, according to the corporate preference and the context, the “tactic module” proposes several prioritized scenarios and collaborates with the company to define a suitable one. Then, with the support of environmental cartography, the operational roadmap is realized which includes the detailed definition about the working process and the responsibilities of each related function. Finally, the KPI system and some transversal supports (the training, communication with stakeholders, etc.) are defined to ensure the operations of program.

14.2.2 Summary of corporate environmental objectives

Firstly, in order to implement the proposition of “convergence” project, a collaborative map among different functions and the actual maturity profiles were realized. Based on these results, the strategic module analyzes the potential improvements about the immaterial capitals and it explored some potential sustainable tendency which might support the improvements. Finally, the global tendency of corporate sustainable development is to **be compliant with the actual European environmental legislative requirements and look for some opportunities of environmental improvement.** According to legislative context of this industry and potential benefits for this company, the strategic module and the corporate president identified three environmental objectives:

- **Fulfillment of the requirements from WEEE directive**
- **Eco label for its products**
- **Augmentation of the product’s recycling or recyclability**

14.2.3 Exploration of all potential trajectories for answering these objectives

According to the presentation into previous section 14.1, the WEEE directive requires the productor:

- to charge the tacking-back of its products or contribute to the common tack-back system for waste

- to response the minimum recyclability rate of its product. According to “article 7” of WEEE directive, the threshold of recyclability is up to 50% of whole weight of product and up to 70% for waste valorization.
- to prepare an “end of life instruction” (according to article 13 of WEEE directive) to support the sorting, recycling, the valorization of electric/electronic waste. But this requirement doesn’t precise the standard structure, the format, and the details of this instruction.
- to print a “WEEE” symbol on product’s tag or on package in order to remind end user that this product is a waste of electronic or electric equipment which should be collected and treated with a special manner. The author resumed that this action doesn’t contain big technical difficulties. So in following planning, the trajectories about the requirements have been ignored.

So in order to comply with WEEE directive, this environmental objective is broken down with three sub-objectives:

- objective 1.1: the calculation and the potential redesign for recyclability
- objective 1.2: realization of end of life instruction
- objective 1.3: either self taking-back system or participate common tack-back platform

Because of the lack of preparatory studies, actually, there isn’t the reference about the status of compliance. So initially, there are two different possibilities, either the products comply the requirements, or not yet. In order to provide a completed version of environmental integration, we presume that some redesigns for recyclability are necessary. So finally, the targeted action for objective 1.1 in the cartography is defined as “action 11.1 calculation of improved product’s recyclability”. According to the evaluation results, if the products don’t comply with the directive, all environmental actions related with the improvement of recyclability will be planned to answer the requirements. Here it’s necessary to mention that although there are large numbers of potential solutions to answer this objective, the requirements of this objective have fixed a part of trajectory: the improvement of the recyclability must be based on the actual results of recyclability rate. So according to this specific condition, the number of potential trajectories has been reduced.

Globally, two scenarios could be implemented. According to the actual product’s recyclability rate, the scenario 1 presents the classic product’s improvement by eco-design, especially by the methods of “Design for recyclability”. Some technical recommendations might be considered, such as the recyclability, the disassembly performance and the economic aspects of each technical option. Meanwhile, the scenario 2 presents the second trajectory to improve the product's recyclability rate by optimizing the collect and treatment of recyclers. Some new actions could be launched, such as the new BATs to be implemented, the collaboration with recyclers that means the product design for optimizing the end of life process. Certainly, the principal input of these trajectories is the actual rate. In order to calculate this rate, the company might use the primary data from the recyclers (if available) or the secondary data from the pre-constructed evaluation methods.

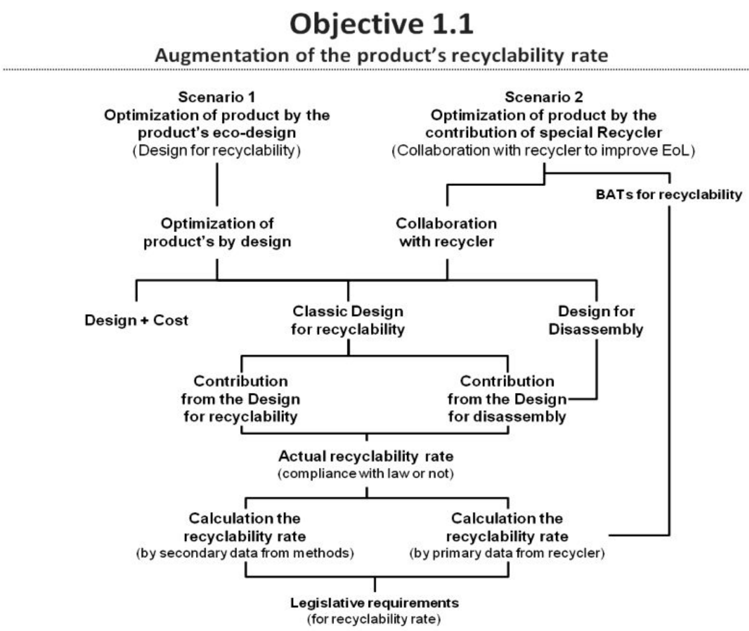


Figure 14-2: The scenarios map (with specific conditions) for objective 1.1 (case study in Festilight): Compliance of WEEE directive by optimizing the recyclability rate of product

Without the normal legislative requirements for the contents of "end of life instruction", the company might identify the auto-description about its contributions for all types of recycling process. Referring to some actual industrial practices, the basic contents include the information about the end of life contact with recyclers, the actual disassembly process for required environmental sensible components. Meanwhile, the contents about all voluntary technical improvement for end of life issues might be included and highlighted into this instruction. These improvements might both support the optimization of the collection, dismantling, recycling process, and the communication for corporate environmental contributions. So finally, in the environmental cartography, in order to support different requirements, the environmental topics related to "end of life instruction" are separated into two objectives: "4.7 Generation of end of life instruction" and "13.4 generation of improved end of life instruction". Similar with the objective 1.1, in order to integrate some potential improvements, the final targeted actions for this objective 1.2 is selected as "action 13.4".

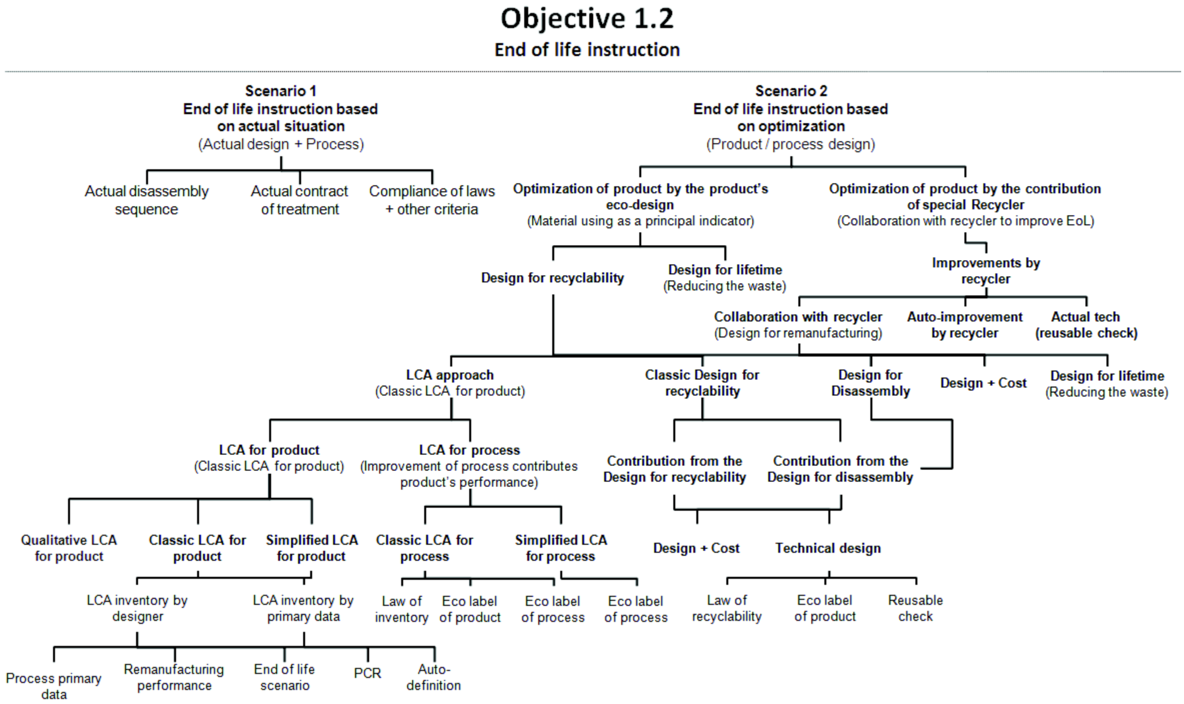


Figure 14-3: The scenarios map (with specific conditions) for objective 1.2 (case study in Festilight): Compliance of WEEE directive by declaring an end of life instruction

For treating the objective 1.3, from the cartography, two potential options could be realized. Firstly, the company might contact with a recycler to treat its waste. This contract might be special for its products or company could participate with a common platform for collecting and treating the wastes. Certainly, the company might charge all reverse treatment activities, such as the collection platform, the remanufacturing process and the logistics for transferring the elements between different factories. So, the targeted actions for this objective are two options: "Action 1.6 end of life treatment contract" or "Action E1 Corporate stock and logistics network management" for its waste.

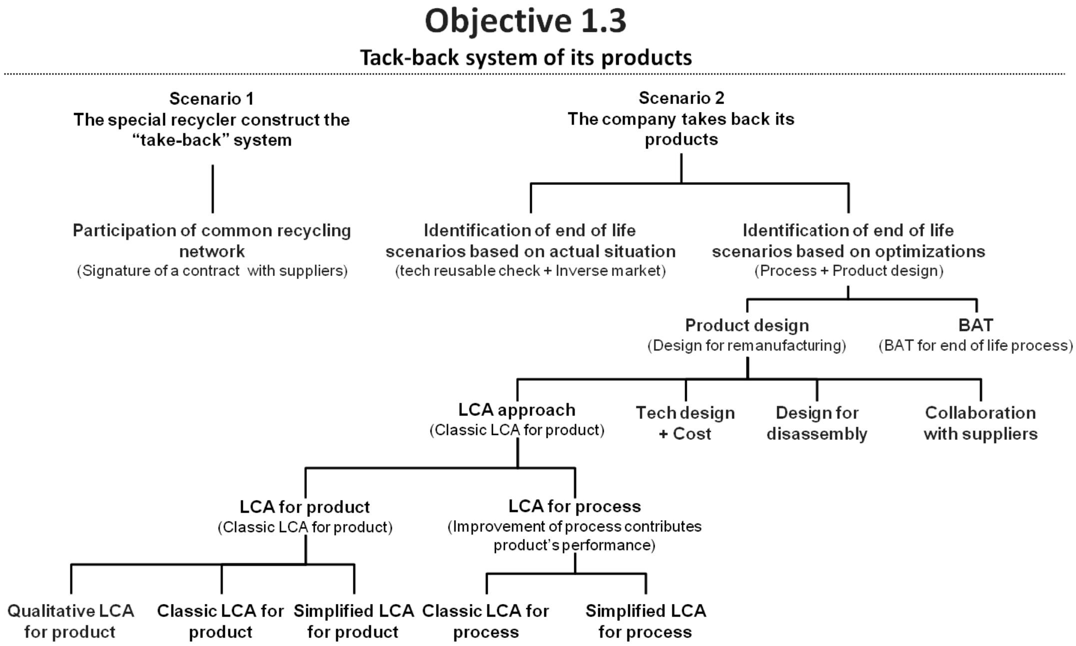


Figure 14-4: The scenarios map (with specific conditions) for objective 1.3 (case study in Festilight): Compliance of WEEE directive by setting up the take back system

Secondly, for realizing the objective of “Eco labeling”, practically, there are several possibilities to be implemented. The first solution is to ask a certification of “Eco label” which requires multi-criteria with the threshold of several environmental indicators to evaluate the product’s environmental performance. ISO 14000 series53 define two different types of eco labels, the type I eco label and type II eco label. The main different of these two systems is the resources of checklist. The type I eco label is organized by external third party and the type II eco label is the auto-declaration from the manufacturer. In the environmental cartography, the final targeted action of these two different labelling systems is same, “Action 13.2, Certification and licensing process for eco labelling”. The second solution is simple. There are a set of particular eco labels which only evaluates one environmental indicator, such as the carbon footprint, the energy consumption and the green resource etc. This solution might be situated as the operational trajectory for realizing “Action 13.5 Certification and labelling process for streamlined impacts”. Thirdly, the third solution is to publish the environmental profiles according to ISO 14025 54 . The targeted action is the “13.1 Certification and licensing process for environmental declaration”.

[53] ISO 14024: Environmental labels and declarations -- Type I environmental labelling -- Principles and procedures
ISO 14021: Environmental labels and declarations -- Self-declared environmental claims (Type II environmental labelling)

[54] ISO 14025: Environmental labels and declarations -- Type III environmental declarations -- Principles and procedures

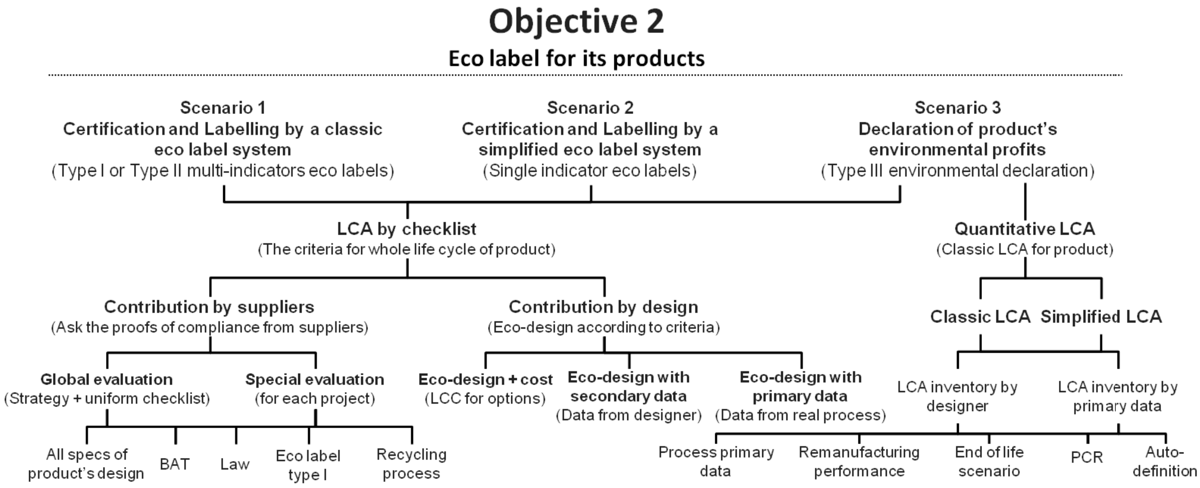


Figure 14-5: Scenarios map for objective 2: Eco label for its products (case study of Festilight)

Similarly to the previous experiment into the company "Quiksilver", the third objective, "Augmentation of the product's recycling or recyclability", covers three possibilities: either the company optimizes the real recycling of these products (such as participate to the improvement of the collection and recycling process, the recuperation of recycled materials into the real product supply flow, etc.), or the company optimizes the design of product in order to augment the recyclability, or the recyclability that is ensured by the suppliers. The final scenarios map is the same with the objective 2 of the precedent case study in Quiksilver.

14.2.4 The generation of systemic scenarios map for all three objectives

According to the targeted actions defined for each objective, we followed the "tracking back" mechanism to explore all potential branches, because the company needs to treat 5 different environmental objectives (the compliance of WEEE directive requires 3 sub-objectives to be done), the next figure 14-6 presents a simplified systemic dashboard to indicate the relationship of all potential solutions:

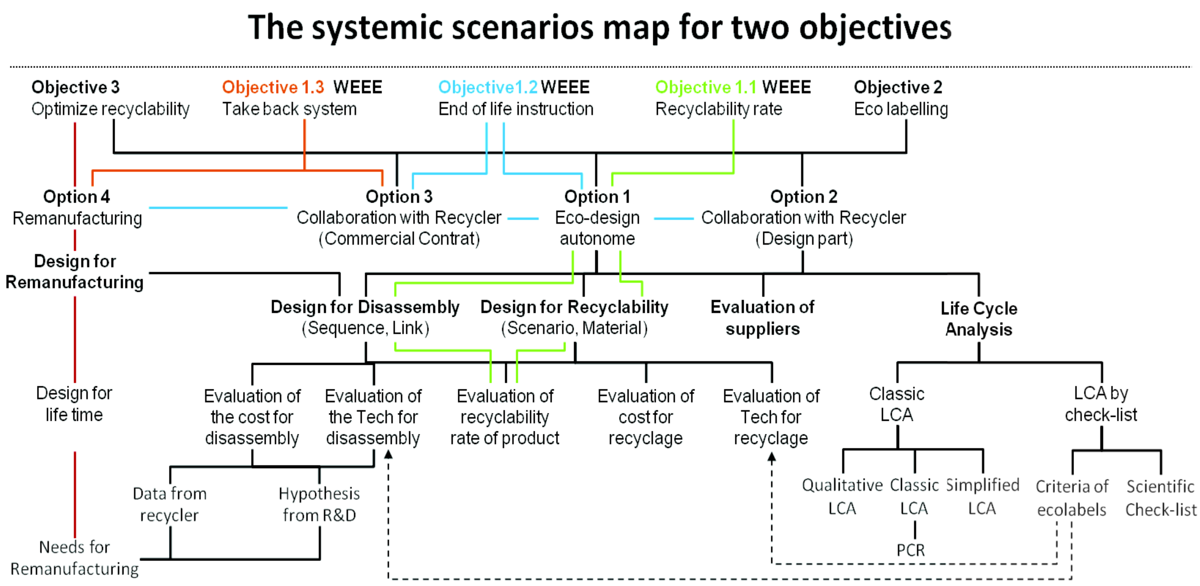


Figure 14-6: A systemic scenarios map including all potential solutions for three pre-defined environmental objectives of company “Festilight”

Black arrow: the potential solutions for objective 2: Design for recyclability
Blue arrow: potential solution for objective 1.1: Compliance with WEEE – Recyclability rate
Green arrow: potential solution for objective 1.2: Compliance with WEEE – End of life instruction
Red arrow: potential solution for an option of objective 3: Requirement for remanufacturing
Orange arrow: potential solution for objective 1.3: Compliance with WEEE – Take back system

The systemic potential scenarios map indicates that in order to answer these three objectives, two main axes of action could be implemented: either the company launches the environmental program alone, or collaborates with the recyclers to make the improvement. From the technical point of view, the Design for disassembly, the design for recyclability and even the different versions of life cycle analysis (LCA) could provide different trajectories for treating a same objective. During the improvement, the company might only focus on the recycling technologies, but it also might generate the re-design ideas oriented form the optimization of the operational cost for certain related recycling process. Certainly, the information about the recyclability and its improvement might be contributed by a new certification of supplier.

Beside these options, the aspect of “remanufacturing” could be implemented for objective 3. As a subject of product’s end of life, the consideration of remanufacturing could be integrated into the “design for disassembly” or “design for recyclability” to provide a systemic redesign, or it could be considered as a special topic to treat about the problems during the reversal process. Certainly, the prolonging of product’s life cycle is also an option to contribute to the improvement of recyclability.

14.3 The preferences of selection and the selected operational scenario

In order to define the “operational preference”, similar with previous experiment, a meeting with the group president has been organized to discuss the real company needs and the operational constraints.

- The constraints about human resource: Festilight is a small size company which only employee around 40 peoples. The R&D team was established from 2011 and there is only 1 engineer who works full-time on site (a manager of R&D team charges some other functions of company. He presents only 20% of his time for R&D activities). On the other side, more than thousand commercial references need to be treated. So the required environmental actions related with R&D team should be quite simple and straightforward for initial program.
- The actual competences of R&D team: Today, the main business model of company Festilight is to purchase all modulated components from its suppliers and assemble them on site to create different decoration. The daily work of R&D team is to create the 2D product design about the assembly of all components. Certainly, Festilight requires the technical details of each component and Festilight tries to collaborate with suppliers to modify the components design, but the topics focus on how to ensure the assembly of final product. Without the strict legislative requirements, Festilight hasn’t touched the details of design for all components (such as the material used, the methodology and the internal structure of each component).
- All main suppliers are situated in China. Meanwhile, some of them are also small size companies which don’t establish the R&D competence to make a depth product design.
- Festilight cooperates with the university UTT (The Troyes University of Technology) to launch studies about sustainable development. An internship has been employed to make the interface between the company and UTT. Two students on master degree are involved also realizing the life cycle analysis of their product.

According to these constraints, finally, the “operational preference” has been fixed as: Under the premise of environmental justification, **the environmental trajectories should be simple and they could be fast and easy integrated into the company.**

14.4 Analysis about the actual knowledge and implemented actions into Festilight

The above section 14.3 summarized numerous potential solutions to treat five pre-defined environmental objectives (the compliance of WEEE requires 3 different sub-objectives). Meanwhile, depending on the environmental information registered into the environmental cartography, the list of required environmental data and the related knowledge has been realized. So this section is to analyze the actual situation about these required knowledge and data into Festilight. This analysis will support the selection of the suitable trajectories according to the "operational preference".

The next table summarizes the implemented environmental projects into Festilight and the list of selected methods.

Project topics	Methods	Perimeter	Results
RoHS compliance	Checklist + proof from suppliers	All products	100% of products
REACH compliance	Checklist + Test by independent laboratory	All products	100% of products
Take back system	Participation into a common collecting platform	All products	Payment of the tax of platform
LED	Utilization of LED	All products	All new products + 98% of professional products
LCA	LCA realized by UTT university	Certain	Certain products

Table 14-2: The implemented environmental projects into Festilight

From this table, it's indicated that Festilight successfully realizes the supplier's evaluation to answer the environmental legislations. Facing the pressure from the law, the related checklist is accepted by suppliers (100% of suppliers have provided the necessary information). And, Festilight frequently collaborates with the main suppliers to co-develop some special products. Meanwhile, the actual participation into the common collection platform has completely answered the objective "1.3 WEEE-take back system".

Here, it's different from the Quiksilver case study. One of the objectives is to comply with the environmental law, WEEE directive. So facing the requirements from this directive, some environmental actions and trajectories have been fixed. From the above Figure 14-6, the green arrows (the calculation of recyclability rate) are mandatory to be realized. These actions require the company to collect the recycling data about its product and to develop the knowledge about the potential improvement for augmenting the recyclability rate. This type of data might be the primary data from recycler or the secondary data provided by the pre-formulated methods of calculation. But till now, Festilight hasn't any experiences and any knowledge to realize the "design for remanufacturing", "design for disassembly" and "design for recyclability".

Based on the actual situation of Festilight, a depth comparison between different options about recyclability has been discussed into the workshop.

Firstly, the consideration about "disassembly" is simplest than recyclability, especially for Festilight. The product's designer on site daily considers how to regroup imported lamps to design a declaration. So their specialties focus on the method to fix, assemble and construct the product. The "Design for disassembly" really requires these competences to optimize the product's structure, the accessibility of joining tools and manners and the facilities of disassembly. Meanwhile, these optimizations might directly affect the product's recyclability, because normally, the recycling rate is better if the components are disassembled.

Secondly, all components are fabricated by the suppliers. Although Festilight requires the quality controlling for all inputs, the modification of materials (especially, outside of the strict demand from REACH or RoHS directive) is difficult to be done. The negotiation with suppliers require a high level influence for affecting the supplier's activities, and it needs a long term period to achieve the objective. As a PME, especially, there are only two product's designers into the company who work for more than thousand commercial references; the "Design for recyclability" might bring too much workloads.

Thirdly, by considering the long term requirement, "remanufacturing", the "Design for disassembly" could directly contribute to this objective, especially for Festilight. The simplest "remanufacturing model" of Festilight is to collect and disassemble the final decoration and directly reuse the components for next product. The better connection technologies might directly optimize the reuse of these components (avoid destroying the components).

And then, for objective about "Eco labelling", the realized LCA of certain products could directly support the requirements of type III eco labelling. Certainly, in order to ask a label from external organizations (such as the EPD organization and the "PEP Eco Passport" association, etc.), it's necessary to integrate the PCRs (Product category Rules: the common standards for life cycle analysis of a special product's category) of thus organizations and modify the environmental inventory of product. The principle actions have been done and the necessary competences have been presented into the company (Festilight collaboration with "UTT University" to launch the LCA). So this time, the achievements could be directly profited to answer the “Eco labelling”. The results of LCA could also provide the references for launching the “Design for disassembly”. Meanwhile, the logo of Type III eco labelling system might be considered as a classic eco label. Festilight might also imprint it on product to indicate that all products have been measured by the whole life cycle analysis of environmental aspects. In other sides, the classic type I is also a potential solution. But it’s necessary to realize a series of preparatory studies about the existing eco labels (The eco label that provides the criteria for decorative lighting product, the market influence, the achievability of technical criteria and the process of labelling, etc.) and it requires also the development of the knowledge about the product re-design to fulfill the criteria.

14.5 Prioritized trajectories for realizing three objectives of Festilight

Facing these three objectives, the first one is mandatory to be realized. The proposed operational trajectory should firstly fulfill all related requirements. So this time, beside of the consideration about the existing environmental actions, the corporate competence and the “operational preference”, all mandatory environmental actions are considered also as the corporate context to select the systemic trajectory for other objectives. Finally, two trajectories were prioritized to realize all requirements. The first provides a basic solution to treat three objectives at same time. According to the “operational preference”, this scenario requires minimum resources and maximum profits the existing environmental activities into company Festilight. Secondly, in order to answer the strategic requirements for “new business growth point by recyclability”, the second trajectory integrates a remanufacturing process into company to reduce the purchasing cost and ensure the guaranty of supply chain. By considering the actual business model of Festilight, this trajectory could not be implemented immediately, it might be considered as a long term program for next five years. Meanwhile, the coherence between two different trajectories ensures the simplification of transfer from the initial activities (scenario 1) to future activities (scenario 2).

14.5.1 Trajectory 1: The simplest trajectory to answer three objectives

This scenario provides a set of trajectories which requires minimum operational resources and competences to realize three objectives at same time.

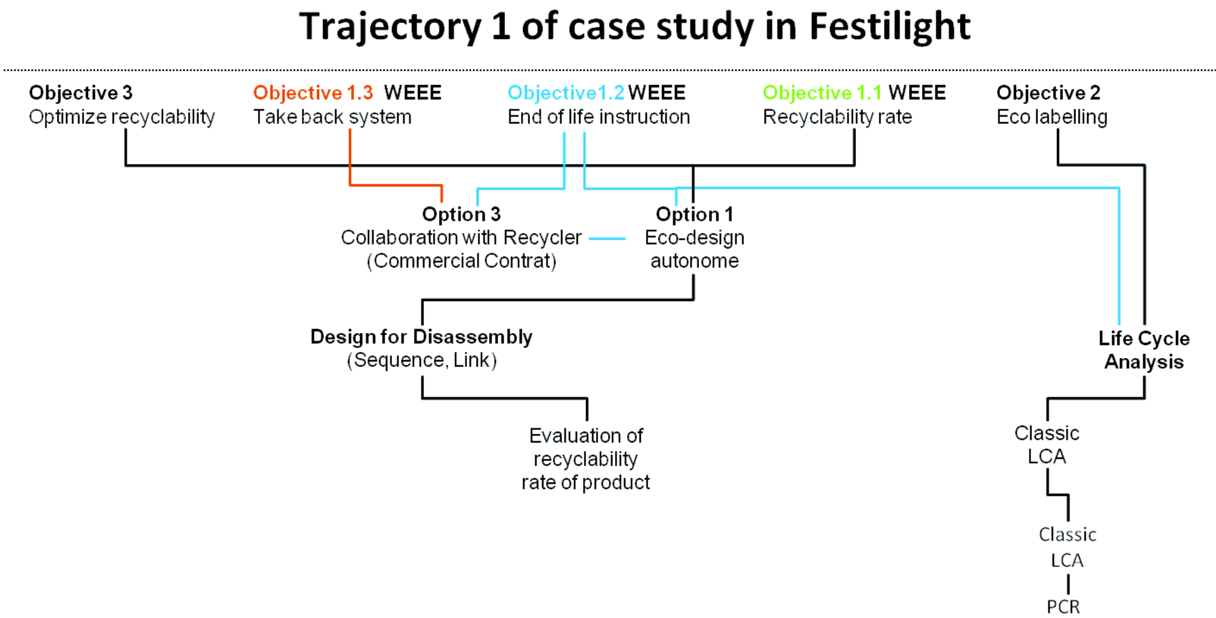


Figure 14-7: First scenario for Festilight – Simplest trajectories for three objectives

Firstly, company Festilight has participated into a common collection platform for its waste, a French national collector "Eco Systèmes"[55]. By profiting this activity, the objective 1.3 about the "take-back system" has been done (orange arrow).

But Festilight should calculate the recyclability rate and provides an "end of life instruction". The option: "evaluation of the recyclability rate" seems mandatory to be selected. Without any data about this rate, some necessary improvement by product's designer was also pointed out to ensure the compliance and contribute the needs of objective 3, the improvement of recyclability. Here, according to the corporate actual situation (the discussion into section 14.4), the "design for disassembly" has been selected. Finally, the type III eco label has been selected to profit the existing LCA results of certain products and to keep the great relationship with UTT University.

14.5.2 Trajectory 2: a long-term planning involving "remanufacturing"

In order to bring the potential optimization about "new business growth point with the contribution of recyclability improvement", for long term planning, the second trajectory adds the "remanufacturing" part to complete the proposition.

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[55] The "Eco-Systèmes" organization, established in July 2005 by 35 producers and distributors, is an eco-organization authorized by French government since 9 August 2006. "Eco-systèmes" ensures a national system for collect, clean up and recycle waste electrical and electronic equipment at end of life (WEEE), with the exception of lamps. The new productor pays annual tax to participate into this organization and thus productor could communicate that it has complied with the requirements from WEEE directive about the "tack-back system".
The official website: http://www.eco-systemes.fr/?gclid=CP7w_bHb3boCFfLHtAod_ikA1g

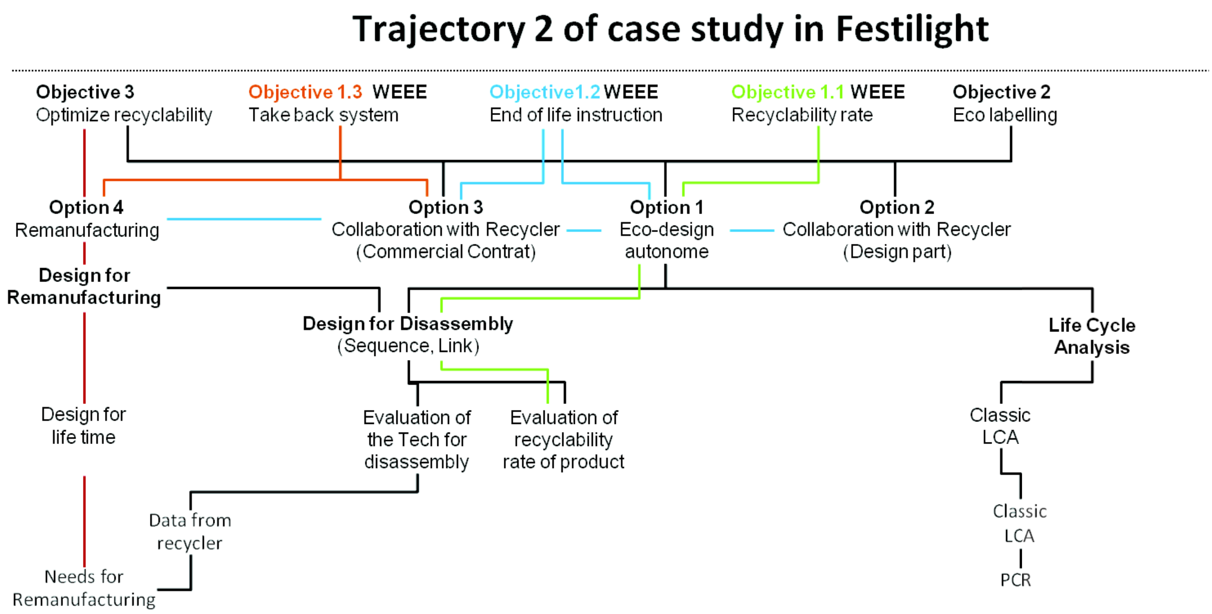


Figure 14-8: Second scenario for Festilight – Long term planning involving “remanufacturing”

Today, Festilight is trying to create some opportunities of B-to-C model which presents a direct business chain between the Festilight and the city hall. With the development of this business model, Festilight might be clear about the volume of waste and its location. This information supports the measure of inverse logistics: the possibility of collection, the possible types and volume of inverse inputs and the delay of transport, etc. Based on the measure, in the future, Festilight might start some preparatory studies about the rentability of the “remanufacturing model”, such as the cost for collecting the waste (either by the specialist, or by Festilight itself), the guaranty of inverse inputs and the new relationship with actual suppliers. If reliable, the “requirements from remanufacturing” could be integrated into the consideration of disassembly technologies to further optimize the product design. Meanwhile, the “Design for prolonging life time” might be added to ensure the reuse of multiple times.

The “remanufacturing” is not a simple process and it requires modifications of the business model, especially, the relationship with actual suppliers. So the implementation of this scenario requires adequate studies of several operational portfolios and it might start only for a product, and then step by step cover all product line.

14.6 The operational planning in order to implement roadmap

The final selected scenario summarized a set of actions and a standard working flow to resolve three environmental objectives. In order to integrate the required actions plan, it’s necessary to designate the related responsibilities of each corporate function and map a working process to contribute to the environmental integration.

14.6.1 The operational roadmap for initial trajectory 1

Initially, according to scenario 1, the required actions are classified as:

- The calculation of recyclability rate to comply with the minimum threshold required by WEEE directive;
- The design for disassembly for "preparing an end of life instruction" and optimize the dismantling of products. This study might ensure the achievement of minimum recyclability rate and it also supports the further requirements from "remanufacturing";
- Eco labelling type III for its products.

The implementing of these objectives requires a preparatory study about the tools or guidelines. Here, the database behind the environmental cartography provides a list of available tools to support these actions. For example, in order to calculate the recyclability rate, there are four different methods. Because the lack of normal method which defined by WEEE directive, these four methods are all available to be used. Meanwhile, the environmental tools database collects also around ten different supports to evaluate the disassembly and suggest the treatment.

Name	Proposal	Description	Reference
Eco D'EEE	End of life	Guideline of disassembly and recycling improvement	[CODDE, 2008]
Design for disassembly guideline	End of life	Guideline to guide the disassembly and recycling improvement	[Chiodo J., 2005]
Disassembly evaluation software	End of life - disassembly	Computer-based methods to identify the "disassemblability" by analyzing the process parameter levels, times, costs and sequence	[Hesselbach, J., 1998]
Disassembly evaluation rating scheme	End of life - disassembly	Quantitative/alternative evaluation of sequences	[Kroll E., 1996]
Manufacturability evaluation for disassembly	End of life - disassembly	Manufacturability impacts on product's disassembly	[Kroll E., 1999]
Cost analysis of disassembly	End of life - disassembly	The cost evaluation and guidelines	[Kuo T.C. 2000]
Fastening and joining selection	End of life - disassembly	Quantitative calculation / software for selection of most economical joining Method	[Shu L., 1999]
Disassembly times evaluation	End of life - disassembly	Time-based numeric indices to each design factor to determine the	[Desai A., 2003] [a] [Desai A., 2003] [b]

		disassembly time of a product	

Table 14-3: A part of list about the available tools for "Design for disassembly"

Third, it's necessary to launch a preparatory study about existing type III eco label system and select a suitable system to be labeled. According to thus PCRs, It must modify and update actual LCA method and related environmental inventory. Once the company has a right result, launch the labelling process.

So finally, it's necessary to nominate a person to analyze them or explore the others and identify a suitable tool and PCR for Festilight.

Today, Festilight is cooperating with UTT (The Troyes University of Technology) to launch the study about sustainability. An intern student is on site and two students on master degree are working for life cycle analysis. So facing the limit of human resource inside of Festilight and the great relationship with UTT, this operational plan proposes the internship or master students to be in charge of all preparatory studies and provide a selection. Finally, the corporate president or R&D manager validates this selection.

Then, once the tools have been selected, the R&D engineer or intern student might launch the calculation of recyclability rate. Meanwhile, when the engineer prepares the "assembly guideline", she could refer to the tools of "Design for disassembly" to consider the disassembly process and make some improvement. The "disassembly guideline", the related suggestions and the recyclability rate might be directly used for constructing the "end of life instruction".

Meanwhile, according to the PCR of selected type III eco label, it's proposed that the intern students modify the environmental inventory and LCA method in order to adapt the labelling requirements. Finally, the R&D manager or administration could charge and follow the labelling process.

The next table summarizes the responsibilities of related functions and the support of work:

Functions	Period	Responsibilities	Support of work	Output
Intern students	Preparatory	Analyze and select a suitable type eco label system (with PCR)	Environmental tools database proposed by Tactic module (List of Type III eco label)	Selected label system
Intern students	Preparatory	Analyze and select a suitable tool to calculate the recyclability rate of products	Environmental tools database proposed by Tactic module (List of available tools)	Selected calculation tool
Intern students	Preparatory	Analyze and select a tool of "Design for	Environmental tools database proposed by	Selected tool

		disassembly”	Tactic module (List of available tools)	
President or R&D manager	Preparatory	Validate the selections of intern students		Selected type III eco label Selected calculation tool Selected tool for “Design for disassembly”
Intern students	Launch	Calculate the rate	Selected tool	Recyclability rate of product
R&D	Launch	Consider the “disassembly” (when prepare the assembly guideline)	Selected tool	End of life instruction (involve the recyclability rate)
Intern students	Launch	Update LCA according to selected PCR	Selected PCR	New LCA
Administration or R&D Manager	Launch	Follow the labelling process	New LCA Licensing process	Type III Eco label

Table 14-4: The detailed responsibilities of each related functions for Festilight scenario 1

14.6.2 The operational roadmap for long term trajectory 2

For long term, the second scenario 1 proposes the integration of remanufacturing into the company Festilight. According to [Nasr N., 2006], [Charter M., 2008], “design for remanufacturing” is a combination process and a concept to consider the product strategy, supply chain management, and the detail engineering of the product for facilitating any steps involved in remanufacturing. So three axes of actions need to be considered: the first axe is the preparatory studies about the rentability of this new business approach; the second axe is the operational process of “remanufacturing”; and the third axe is the product design and purchasing integrating the aspects of “remanufacturing”.

14.6.2.1 Preparatory studies about rentability

Firstly, the “remanufacturing” is a new business model which modify actual structure of supply chain. The company might reduce the volume of purchasing from external suppliers and profit the reversal flow of its waste to complete the inputs. So before the launch of this new model, a rentability analysis is necessary to be launched. This analysis might focus on:

- The statistic about the waste types, volume, thus quality at end of life (reusable check) and the actual or potential waste collection system.
- According to actual waste volume and the performance of collection system, does the reverse logistics could ensure the stability of inputs? Certainly, different performance of waste collection might be simulated to demonstrate the development tendency.

- Facing the negative influence on supplier relationship due to the reduction of purchasing volume and the additional inverse logistic/production cost, how many percentage of remanufacturing is reliable?
- Based on economic consideration, which component has the value for tack back and remanufacturing? Certainly, under the assurance of the quality at end of life, the common components for large number products, and the components present a high purchasing price have the highest priority.
- Which technical improvements might be launched to optimize the “remanufacturing”.

The clarity of these questions is very important to make the decision if the Festilight needs a remanufacturing process and how to organize this new process. This analysis requires some economic simulations of rentability, the statistic of detailed corporate data and the depth knowledge of remanufacturing process. Here, we propose the involvement of external expert, such as the expert in UTT to launch this preparatory study.

14.6.2.2 Operational process of “remanufacturing”

The remanufacturing could be considered as a new inverse supply chain. It means that in order to recover the remanufactured parts in the new product, these recovering material flows should be involved into the supply chain management as a new component purchasing. A normal remanufacturing process is described as below:

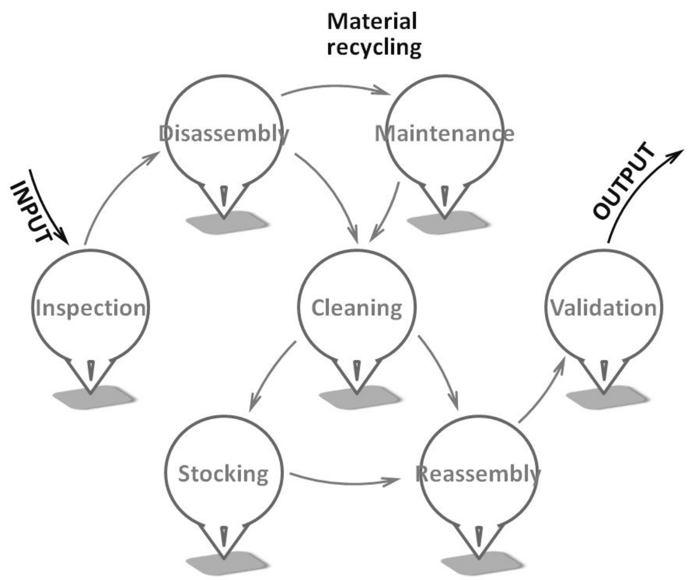


Figure 14-9: The operational process of remanufacturing

The first step is to establish a waste collection system. This logistic network could be constructed by Festilight (only collect its waste) or charged by external distributor. The self inverse logistic network could directly profit the auto-improvement by "Design for disassembly" and other technical evaluation for suppliers, such as the guaranty of components life time, the quality at end of life, etc. Meanwhile, the self-charged logistic network could adapt the capacity of stocking and inverse production.

The commercial team, especially, the administration of commerce could firstly maps a detailed distribution summary of all sold products. According to actual requirements for new products, the supply chain team can analyze the available types and volumes of waste to organize the flow of inverse materials.

Once the used products arrive, there is a series of actions that need to be implemented by production & Stock team. Firstly, at the point of inspection, it's necessary to validate the real quality. A technical test is mandatory to identify malfunctions / fails of all inputs. If possible, this test needs to be realized at component level.

Secondly, according to the fail report, the production team might disassemble the product. At this moment, the realized "end of life instruction" could be directly used to guide the disassembly process. The component still valid might be stocked and the non-validated components could be resold to external recycling center. Certainly, if necessary some simple maintenance will be done for repairing some non-validated components with high value.

Thirdly, after the step of cleaning all disassembled components, these inverse inputs could be considered as normal inputs which will be managed into normal production process and logistic network.

Finally, several available tools that support the decision of each axe are provided to Festilight.

Tools	Format	Key Purpose	Feature	Author(s)
Component rentability assessment	Quantitative Calculations	Remanufacturing strategy decision making	Customer focused Process oriented	[Zhang T., 2010]
DfRem guidelines	Qualitative Reference	Guidance	Simple Offers guidance	[Ijomah W., 2007[a]] [Ijomah W., 2009]
DfRem metrics	Quantitative Calculations/ Software	Assess of remanufacturability	Process oriented Familiar concept	[Bras, B., 1996] [Amezquita, T., 1995]
DfRem metrics	Quantitative Calculations/ software	Assess remanufacturability Suggest improvements	Lifecycle thinking. Offers guidance	[Willems, B., 2008]
Energy comparison tool	Quantitative Calculations	Compare manufacture and remanufacture energy usage	Lifecycle thinking	[Sutherland J., 2008]
Hierarchical decision	Quantitative Calculations	Design of product architecture for most	Lifecycle thinking	[Lee H.B., 2010]

model		profitable disassembly		
MCDM	Qualitative	Multi-criteria	Offers guidance	[Jiang Z.G., 2011]
RemPro matrix	Qualitative Reference	Guidance, prioritization of issues	Simple Offers guidance	[Sundin, E., 2004]
REPRO2	Qualitative Software	Decision making, providing past examples	Early in design process No required extensive knowledge. Offers guidance	[Zwolinski, P., 2008] [Zwolinski, P., 2006] [Gehin, A., 2008]
RDMF	Qualitative	Remanufacturing Decision-Making Framework Questions	Process oriented Simple Offer s guideline	[Subramoniam R.,2011]

Table 14-5: The list of available tools of "Design for remanufacturing" in environmental database of tactic module

14.6.2.3 Product design and purchasing consider the aspects of "remanufacturing"

Once the remanufacturing process is validated, the product design and the components' purchasing need to consider the aspect of remanufacturing to optimize the final economic performance. The purchasing of the components with longer life time is a better point that might be integrated into the supply chain strategy. Certainly, the supply chain team might contact with main supplier to ask these required data and integrate them into the supplier selection checklist. On the other hand, the implemented "Design for disassembly" might be directly used. Meanwhile, facing the remanufacturing process, such as the clearing process and stocking, some special design to simplify these processes might be also considered by R&D department.

14.7 The discussion and the conclusion of this experiment

In previous experiment in the Quicksilver Company, the results indicated that the proposed "Tactic module" and related "environmental cartography" could provide a systemic view of potential solutions and support a suitable selection of a right trajectory. This second industry experiment selected a small side company to validate if the proposed models are also available within the context of SME.

Compared to Quiksilver, Festilight, this small size company is without a clear definition of internal working process and of the responsibilities of each function. Meanwhile, due to the limited size of the company, some functions could not provide a complete support for environmental integration, such as the R&D team only employees an engineer. Facing this different context, the project "convergence" organized a workshop during three days to identify the suitable environmental trajectories to answer the strategic needs for corporate development. Here, also three points need to be highlighted.

14.7.1 Tactic module provides Non-Standard solutions depending on actual environmental achievement

The environmental cartography covers a large number of environmental actions and it identifies the systemic interactions among them, so it's possible to generate the non-standard trajectory to break the standard inertia of thought.

In this experiment, in order to answer the second environmental objective - eco labelling of the product, the company Festilight and its intern students thought to ask the license of classic type I eco label. But actually, there isn't the eco label system defined a checklist for decoration service, usually, only for lighting product. Meanwhile, multi-criteria of lighting product require a set of product optimization, and some of they are out of scope of company's capacity. Once the launching of the exploration of potential solutions, the workshop found out the type III is also available to answer this objective. The life cycle analysis has been done by external intern students, and the company has the completed competence to modify the differences between the actual LCA inventory and required version. Meanwhile, the logo of type III eco label system could be also profited to demonstrate that the product has been evaluated basing on the life cycle consideration. And this demonstration might support the needs of communication of product and corporate mark.

Type III eco label is not a standard communicative solution for B-to-C marketing. But in this case, this type of eco label is considered as the best choice, because it could directly use the existing environmental achievement; avoid the operational risks (the criteria are out of scope of company's capacity); and simplify the operational process.

14.7.2 Tactic module provides a systemic view for supporting the multi-steps operational planning

In this experiment, the proposition of environmental trajectory is not only for a new collection. The proposed scenario should be coherent with the long term tendency of corporate development. In time, there are three environmental objectives: 1) the first is the compliance with WEEE directive; 2) the eco labelling of products; and 3) the improvement of product's recyclability which might be realized via the potential "remanufacturing" in long term. Since 2005, the WEEE directive has enforced. So the first objective is mandatory for company to be immediately realized. Meanwhile, because of the selection of type III eco label, the labelling process becomes simple and easy to do. These objectives are considered as short term objective for the first scenario. And then the third objective has several possibilities to be realized. Festilight might evaluate its suppliers to demonstrate the recyclability of its product; it could contact recyclers to improve the collection performance; meanwhile, it might also profit the LCA results to modify the potential treatment scenarios and product's materials. But facing the potential requirements about "remanufacturing", the "design for disassembly" is a common solution to answer both the short term and long term objective. Firstly, this type of redesign is enough simple for Festilight, especially there is only an engineer present in R&D team. Secondly, on one side, this redesign could directly support the optimization of recyclability rate (it's required by the first objective), the contents of "end of life instruction" and the results of this redesign could answer the first need of objective 3, the improvement of product's recyclability by the consideration of disassembly process. Meanwhile, on the other side, this redesign is a very important part to contribute to the "remanufacturing" aspect. The implementation of "Design for disassembly" might be considered as the pre-actions of "remanufacturing". All consideration about the coherence and the final selection of common trajectory demonstrate the systemic view of all potential solutions and the interactions among them might support the improvement of environmental integration into the company.

14.7.3 Tactic module provides a systemic summary of potential solutions which ensure the further depth analysis of the implementability of each solution

Facing the corporate context and environmental objective, the proposed scenario 2 presents a long term plan which involves the "remanufacturing" approach. Because this new approach requires a new business model which will break the actual supplier relationship and affect the corporate revenue. So beside the analysis of risk and achievability, a detailed rentability analysis should be done to validate if the company needs to step by step change to new model. In order to support this need, the environmental tools database behind the cartography provides the detailed checking points that need to be considered. In this case, three axes of actions are required to analyze, and in each axe, a list of checking points are provided to support the decision. So facing these important environmental issues, the environmental cartography could provide a first selection. A depth analysis (with multi-indicators) is required to complete the decision support.

14.8 Conclusion of the efficiency of the "Tactic Module" through the case study in Festilight

Depending on the proposed environmental cartography and "tracking back" mechanism, this chapter presents how to support a small size company to identify the suitable environmental trajectories in order to realize the predefined environmental objectives. Compared to Quiksilver, this small size company has the limit of human resources and knowledge which require a simple and direct operational trajectory.

During the three days of workshop into company, by the support of environmental category, the workshop generates several different potential trajectories to answer the requirements. And depending on the corporate context and limit of human resources, a simple trajectory has been proposed. This trajectory fully inherits the existing environmental achievement to finish the pre-defined objectives. During the discussion, this systemic cartography ensures that the company generates some new non-standard solution to treat a typical problem. Meanwhile, a common and adapted solution "design for disassembly" has been pointed out to support the needs of all three objectives. This systemic planning doesn't only make the coherence between different environmental objectives, but also support the coherence between the short term and long term program. And then, the environmental tools database provides a tools support for small size company.

Certainly, we found out that it's necessary to establish a depth analysis for some very important issues which affect the business model and rentability of annual revenues. And then the environmental cartography and the tools database might support a first pre-selection and they could provide a detailed checking list for further analysis with multi-indicators.

Chapter 15 - Conclusion of three experiments

This part V aims to define the sequence of experiments that enrich the knowledge in the practice of environmental integration and get the demonstration of the validity of the scientific propositions of this thesis. Finally, there three experiments have been done. Firstly, based on the environmental cartography and the “tracking back” mechanism, a serious game, named “SimGreen”, was created to validate if above propositions might support the systemic environmental integration. The principle purpose of this game is to push the player to identify a suitable trajectory by considering multiple dynamic objectives and the limit of operational resources. This serious game was firstly organized for academic lessons of French engineering school to validate the concept. Meanwhile, this game was animated with several environmental experts from IFTH (French Textile and Apparel Institute) and the G-SCOP laboratory to further justify the pertinence of the proposition. With the numerous discussions about the action chains of each environmental objective, the environmental experts proved that the proposed cartography and scenarios maps could correctly support the company to take a more systemic view about the potential solutions. This systemic view of various solutions ensures the company to select an adaptive trajectory depending on corporate strategic needs and its dynamic context.

Secondly, in order to ensure the operational robustness about the proposals of “Tactic module”, there are two experiments were organized in two different companies: first case study is into one of world leader companies, Quiksilver and the second case study is into the Festilight that is a SME for decorative and festive lighting service.

The feedback double demonstrates that the “environmental cartography” successfully provides a systemic and depth support to explore a various numbers of potential operational trajectories which harmonize the environmental actions of product and site-oriented approaches to answer the objectives. Then, the multi-indicators to evaluate the potential trajectories allow the company prioritizing and selecting the most suitable operational solution according to its particular context. And the definition of the interactions among different environmental actions support also the efficient planning of the working processes and the responsibilities of each related functions. Meanwhile, the case study into Festilight demonstrated that this systemic planning doesn’t only make the coherence between different environmental objectives, but also support the coherence between the short term and long term program. And then, the environmental tools database provides a useful tools support for fulfilling the environmental activities into the small size company.

VI

CONTRIBUTIONS AND PERSPECTIVES

This part focuses on the contributions of our research work in order to optimize the integration of environmental issues into company. At first, the problematic of this research have been presented. Today, facing the various environmental initiatives, the industry requires a systemic approach to support the decision about the environmental program planning. In order to answer this problematic, a French research project “Convergence” has been launched. This thesis represents the “Tactic module” of this project to contribute to a systemic selection of a suitable operational trajectory depending on the dynamic corporate objectives and context. A depth analysis of existing environmental practices is discussed. We then propose an environmental cartography and the “Tracking back” mechanism to facilitate the integration of environmental trajectory into company. Finally, we present the advantages and limitations of its application and propose research perspectives.

Chapter 16 - Contribution of this research work

Actually, facing more and more environmental problems and the limit of material resources, to take into account environmental aspects in industrial activities becomes more and more important. Today, the industrial sector plays a fundamental role to develop a new business model which is more compatible with sustainable development of human society. Facing the various environmental requirements and a large number of environmental initiatives, our research work focuses on providing a systemic management tool to facilitate the integration of environmental considerations into company.

Our analysis of the bibliography shows that it's necessary to develop a uniform method to select the environmental tools by considering the real corporate objectives, the dynamic context and the interactions among different related tools. The aim of this uniform method applied in a company is to generate a more efficient trajectory to answer the environmental objectives.

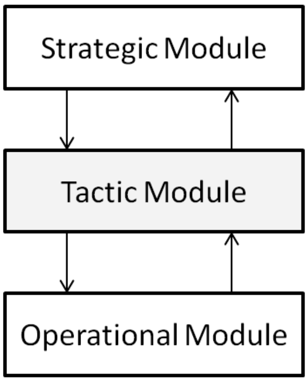
Meanwhile, till now the product-oriented methods (such as life cycle analysis and a series of tools about design for X) and site-oriented methods (the environmental management system and the inverse material management, etc.) are still considered as two independent domains to be resolved. But actual various environmental practices indicated that there are some interactions among them. The site-oriented approach affects the results of product's improvement, and vice versa. So the author presumes that a systematic conversation channel between the two different approaches could identify a suitable planning which optimizes the efficiency of environmental integration.

Thirdly, the environmental activities require the contribution from multiple corporate functions. So it's necessary to create a systemic approach to optimize the decisional and informational circulation among the whole company. The strategic decision requires a systemic environmental knowledge support to analyze different portfolios and its related benefices. The operational integration needs a clear definition about the working process and the responsibilities of each function. So in order to communicate among the whole company, it requires a systemic view of all environmental necessities to provide a global planning.

Facing this problematic, the author proposes that **a systemic view is necessary to organize a global integration of environmental actions.** This systemic view should ensure:

- Coherence among all selected eco-methods or tools, by managing the flow of informational exchange
- A systemic approach which includes product-oriented methods and site-oriented methods
- Coherence between environmental decision and corporate dynamic objectives and context
- A global approach to support the strategic decision and the operational integration

In order to answer these needs, a global research project called "Convergence" has been constructed. The final objective of this project is to determine whether sustainable integration could be improved by better cooperative circulation among different company levels, and to propose a navigation-based approach to support this improvement. This navigation-based approach does not only focus on the informational exchange model at the interface of different corporate levels, it also analyzes and provides the practical methods to support the environmental decisions at each level.



This thesis contributes to the development of the middle module called "Tactic module". The objective of this module is to identify a detailed and systemic environmental working flow in order to answer the requirements of corporate strategic plan. The interfaces related to the "strategic module" and to the "operational module" are adapted to ensure the decisional flux circulation. According to the structure of the proposed "vertebral column" model, the contribution of the tactic module is described as below:

- A large environmental expertise to support the strategic decision
- A systemic approach identifies a suitable environmental trajectory to answer the strategic attend. This systemic approach need to comply with the above four requirements from the problematic
- A clear environmental roadmap to support the operational integration

16.1 A large environmental expertise to support the strategic decision

Facing the diversity of environmental drivers and a vast number of environmental methods, firstly, we tried to analyze as most as possible methods and practices. Finally, more than 300 environmental tools and industrial practices have been analyzed. These literatures were regrouped into 46 environmental objectives (20 for site-oriented approaches and 26 for product-oriented approaches). For each environmental category, referring to several literatures, the author tried to normalize the working process by a series of operational actions. Finally, 126 standard environmental actions have been proposed. Using a "resource-based" point's view, the actions are described by four elements: the objective, the necessary inputs, the outputs and the necessary competences. The related methods and tools are listed also to support the implementation of each action.

Then, we presumed that the collaboration between different environmental tools appears at actions level. It means that the output of an action doesn't only answer the needs of original environmental objective, but it could also affect other actions of other objectives. So, three types of interactions have been identified to describe the relationship among the actions. Finally 186 interactions have been identified. This definition of interaction at action level allows the de-correlation between the environmental topics, and it ensures the flexibility for generating different solutions for an objective. Till now, the environmental methods or tools are only considered as packages of actions, and the company is allowed to regroup several actions (following the interactions) to construct its particular solution to realize environmental objectives. Meanwhile, the interactions at "action" level might ensure the coherence between different environmental approaches, especially between product and site-oriented approaches

Finally, there is a cartography of the environmental actions has been proposed. This cartography includes several environmental objectives a "Tracking back" mechanism ensures the generation of multiple trajectories to answer the chosen strategic requirements. The "tracking back" mechanism could also generate the trajectories according to some special constraints, such as the mini operational area (ex: find out the solution only for R&D team), the corporate predefined preferences and the multiple objectives to be treated at the same time. Meanwhile, without the predefined environmental objectives, the "tracking back" mechanism could explore also several new potential environmental deliverables by maximum profiting the actual achievement.

Using this support in the strategic module, we are able to realize depth analyses to identify the strategic tendency about the environmental integration. The implemented environmental actions might optimize also the corporate material and immaterial capitals.

The environmental cartography is open to be modified and updated to integrate new environmental tools being developed. Moreover, during the process of execution, the company has to find out some other new "interactions" among the executed actions. These new discovers could complete and update the environmental cartography and they ensure the generation of more new trajectories.

16.2 A systemic approach to identify suitable trajectory to answer strategic attend

The previous section shows that we are able to generate numerous potential trajectories to be implemented in order to resolve a concrete environmental objective. But because of the limit of corporate resources, the company needs to evaluate and prioritize among alternative solutions, to implement these priorities and to follow up on their effects. So the difficulty is to identify a suitable solution according to the real corporate requirements and his context and finally to follow the progress status of all related activities. The “Tactic” module, as a central module of this systemic approach, provides a systemic working plan by considering the coherence with dynamic strategic decision and the operational conditions.

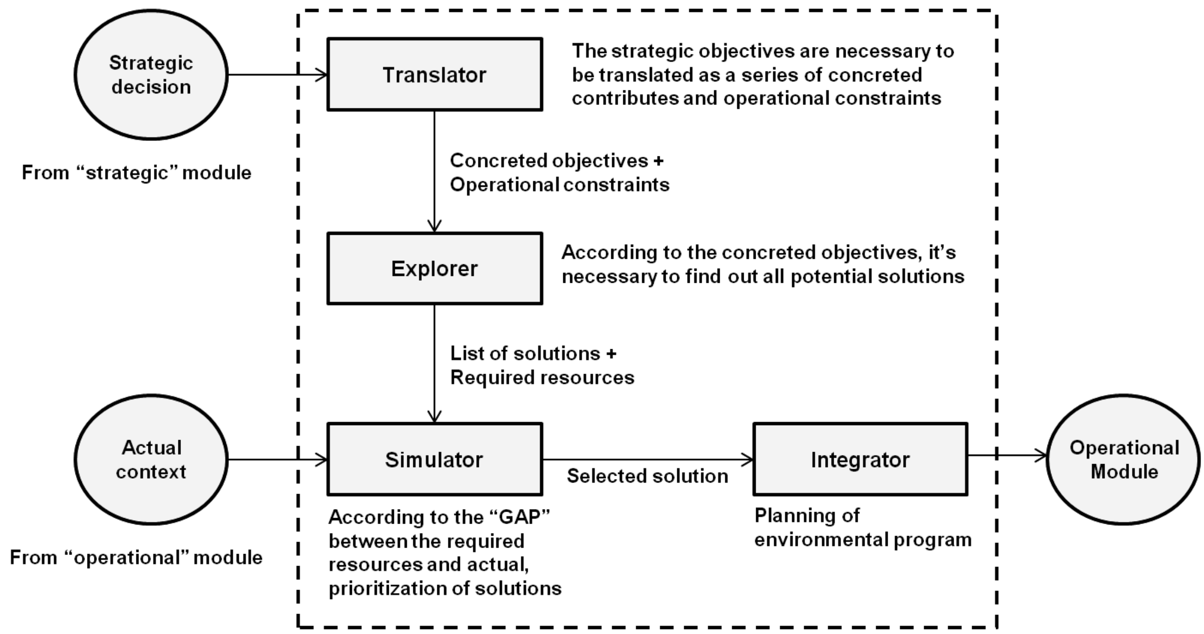


Figure 16-1: General framework and working flow of the “tactic” module

The mechanism of the “tactic module” ensures the integration of strategic objectives and related operational preferences to select a suitable trajectory. The operational preferences include the consideration about the cost, the time frame, the operational complexity and the final influence. So, even if the objective is the same, but the selected trajectory might be different by considering different operational preferences.

On the other side, using the comparison between the required operational resources and the actual corporate state, this mechanism ensures the integration of dynamic context to make the decision. Meanwhile because the implemented environmental actions and actions to be implemented could modify the corporate state about the knowledge and related environmental data, this mechanism might integrate also the influence from implemented actions to make the decision.

Then, facing the multi-objectives and because the numerous interactions have been identified, the “tracking back” mechanism could explore some common trajectories which could answer multi-objectives at the same time. The sharability of environmental actions might reduce the operational complexity and cost. And finally, it encourages the company to integrate the environmental consideration.

Finally, it’s necessary to mention that the whole cartography provides several trajectories for each concrete environmental objective and that each trajectory is independent and can completely resolve the objective. Once the company makes a selection according to its particular context, only one trajectory is picked out. So inversely, for this environmental objective, there are also a numerous possible alternatives. So, during the implementation process, when a selected trajectory cannot continue to be executed because of the changing of corporate status (i.e. a key competence lost or a new cost down strategy, etc.), this redundant design can quickly perform a variety of other possible backups to fulfill the final objective. Meanwhile, some executed actions will be considered as the new corporate status. By considering this operational update, a more compatible trajectory is proposed. So, the multiple possible data connection pipes (the interactions among different actions) and multiple contributions of trajectories enhance the robustness about the key resources.

16.3 A clear environmental roadmap to support operational integration

The integration of environmental issues requires finding out a systemic operational trajectory. It also need a clear plan to organize the details about the timetable of each action, the responsibilities and working manner of each action and related corporate functions, and the working flow among different environmental actions.

Facing this type of requirement, the trajectory doesn’t only provide the macro solutions to treat the environmental objectives for global planner of environmental programs. It also breaks down the whole trajectory into a series of implementable actions; thereby it disperses all operational necessities inside each node or action of the trajectory, such as the responsibilities, the treated information and the required competences. Each node only focuses on its necessities and all data of the whole trajectory are stored in each action. The relevant corporate departments of each action can only clearly understand the working details of this action and the interface with others. It's not necessary to consider the details of other actions. Meanwhile, the outputs of each action can be considered as a series of deliverable documents which have registered the targeted environmental results of this action. Such decentralized structure of data registration ensures the clarification of the responsibilities and working performance of each action and each corporate function. It further ensures an efficient training and internal communication which delivers the adequate information to each relevant person.

Secondly, the outputs of each action don't only contain the environmental data or results, they also include the knowledge to collect and generate these data. Each output stocks the intangible knowledge into the tangible document. For implementing again this action in the future, the decentralized stocked knowledge could easily be targeted, prepared and analyzed. It enhances the capacity of existing knowledge inheritance.

16.4 Conclusion on our contribution

Our research contributes to a real need for industry practices. The main scientific contribution is to provide a systemic and comprehensive approach to harmonize various environmental expertises. We propose a navigation method to pilot the company, and to generate and select a suitable environmental trajectory by considering the coherence with strategic decision, the operational context and other implementing environmental approaches. Three case studies demonstrate that this research optimize the globalization of environmental program planning and augment the efficiency during the planning period.

Chapter 17 - Limits and Perspectives

We tested the mechanism of the "tactic" module with the environmental cartography in two French companies, Quiksilver and Festilight. All propositions of this thesis have been implemented to support the generation of operational programs. During the planning period, the feedback is positive. This research could optimize the globalization of environmental program planning and augment the efficiency during the planning period. However, we can't verify the achievement of actual decision or whether it will be updated and modified thereafter (the new requirements arrive, the change of operational context, etc.) But the author presumes that any modification of trajectory follow the same process of the initial planning. So the actual success might ensure the support for any modification in future.

Today, the environmental improvement is considered as a contribution of sustainable development. But the environmental consideration couldn't cover all sustainable aspects. The social responsibility is another big sector which could be ignored. Sometimes, the environmental aspects and social issues are correlated. During the case study in Quiksilver, the company required a larger intelligence support (with the social issues) for strategic sustainable decision. And they asked also how to integrate the location of the suppliers to make the supplier's selection. Beside of the analysis of global environmental impacts, the local environmental influence, the state of human right or child labors need to be considered as to select a sustainable supplier and develop a sustainable product.

Meanwhile, as mentioned into the Quiksilver case study, the proposed tactic module doesn't provide a detailed mechanism to highlight and integrate the operational risks to make the final selection. In this version, the risks are hidden into the informational flow between the different actions. It's required to develop an analysis about the availability of each output to measure the operational risks.

Several users' feedback indicated that there is lack of some popular environmental objectives, such as the design for reuse. This environmental objective has been separated in two different: prolong the lifetime and (if only a part of the product will be reused) design for remanufacturing. The main purpose of this separation is to simplify the environmental actions into the cartography by regrouping the similar environmental actions. Similarly, the end user can't find out the objective about the WEEE directive compliance, because this objective has been separated as three sub-objectives: the calculation of product's recyclability + the design for recyclability; the generation of end of life instruction; and the taking back system. So before the use of this cartography, it's required to analyze the list of proposed environmental objectives and to address the right group to launch the exploration.

However, in short term, in order to diffuse the research results, several tools and communication plan will be developed:

- Firstly, in order to simplify the playing sequence of serious game "SimGreen", a digital version of this game will be developed. Meanwhile, with the strong support from IFTH, this serious game will be diffused and communicated into the textile industry to support the environmental training.
- A digital version of the "systemic environmental planning tool" is being developed by convergence project. All proposals of this thesis will represent the "tactic" module to provide a systemic integration planning about suitable environmental actions.
- The communication about the research results will be done by the scientific seminars, the industrial workshops and the articles of scientific conferences and journals.

However, the limits of actual research pilot two prospects researches in long term:

- Several social topics will be integrated (such as the ISO 26000, human right, the label certification of social responsibilities, etc.) to contribute to a more systemic propositions for sustainable development.
- Operational risks for each trajectory will be highlighted and a risk analysis will be directly integrated into the mechanism of selection.

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Annex

Analysis and Guideline for using the existing Environmental methods and tool

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General Introduction

With the “environmental concern” concept being gradually understood and accepted by the public, the industry is now facing to the green challenges. On legislation level, the industry should face a stricter legislative environment which is under accomplishment over time. Some countries and country unions (such as European Union) have developed or are developing their environmental regulations to accelerate the environmental improvement and educate the public to take care of the environment. Legislative framework including directives like RoHS, REACH, WEEE, ERP and Battery etc., which is developed by European Union, could be considered as a great example, and this law system is being considered and translated into some local versions by other countries. At the same time, there are now not only the legislative regulations released to demand the “ecologically necessary” [Manzini E., 1992], but also the growing diversity of the green requirements from the clients to improve their life quality. More than a third of US consumers now say that they are willing to pay more for eco-friendly products, and in some cases this is even higher and 44% of UK consumers want more information on what companies are doing to be green [Global Ecolabel Monitor, 2010]. Final customers care about environmental issues and accordingly, in Business to Business mode, downstream enterprises need the environmental proof to make their green offers (Product/Service) to answer the requirements from their final customers.

In order to answer these above-mentioned requirements and enhance the competence of competition, a vast range of eco-design methods, tools and concepts have been developed [Kemp R. et al., 2004], [Baumann H., 2002] and [Uger N. et al, 2008]. The hazardous materials avoidance, the product’s end of life performance, the energy efficiency, the 3R or 4R concepts…… more and more environmental aspects are integrated to the environmental framework. Moreover the implementing measures can be diversified on the same aspect, increasing again the number of available methods. [Ilgin M.A., Gupta S.M., 2010] summarized more than 500 scientific contributions in “product recovery” domain. These proposed methods improve some related aspects which could be classified into two categories; the reversal network design and the product design for recovery. Even only for “design for remanufacturing” aspect, [Hatcher G.D. et al., 2011], provided also a holistic analysis of 10 existing “design for remanufacturing” software and tools which address multi-types objectives by requiring different implementing resources. Then the viable corporate strategy and the complex context might also require different applicable methods, such as the straightly focusing on the environmental performance via some initial eco innovations or the minimum response of mandatory external requirements. So, the growing number of environmental methods, concepts and tools really leads to a new challenge: How to evaluate the relationship and hierarchy of them and how to identify the suitable methods to build the sustainability of enterprises.

With the presence of numerous environmental methods / practices and according to the dynamic environment of the company, in order to support the integration of “eco-design” in the company, a holistic and systemic view of existing eco-design methods and tools is necessary to organize overall corporate environmental activities. Facing to this requirement, one hypothesis has been indicated that a more profound identification of the existing environmental methods or solutions could support the establishment of this systemic perspective. To respond more specifically to the problem, this report presents a static base of existing environmental methods with a series of their specific characteristics (the purposes, the actual situation of method development, the related environmental activities, the typical process of realization, the required competences and environmental data for each step and same examples of existing tools).

Meanwhile, the “eco-design” is not a pure activity of product designer, it requires the collaboration among different internal/external stakeholders to complete and further improve the product’s environmental profits. So beside of the typical product-oriented eco design methods and tools, some related environmental activities at corporate level are presented also to complete the systemic perspectives (such as the signature of the treating contact with the recycler and the supplier management, etc.).

Product-oriented LCA

The product-oriented LCA is a quantitative technique to analyze environmental impacts associated with all the stages of a product's life cycle phase, from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling. According to the standards of ISO 14040 series, the typical analysis process of LCA includes 4 steps:

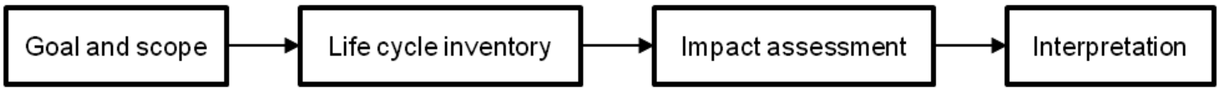


Figure 2: The process of product-oriented LCA

Goal and scope: to launch a product—oriented LCA, the first step is to identify the context, scope and goal which might include these following technical details to guide the next work:

- Function unit: it defines what precisely is being studied and quantifies the service delivered by the product system, providing a reference to which the inputs and outputs can be related.
- The system boundaries: The frontier of elementary flow should be considered.
- The assumptions and limitations: The hypothesis to identify the rules of data collection and the data quality.
- The allocation methods: used to partition the environmental load of a process when several products or functions share the same process
- The impact categories chosen: The identification of environmental indicators (such as GHG, waste pollution etc.) to evaluate the environmental impacts

Life cycle inventory

It involves creating an inventory of flows from and to nature for a product system and the functional unit defined in previous step. Inventory flows include all inputs of water, energy, and raw materials, and all releases to air, land, and water. To develop this inventory, a flow model of the technical system is constructed using data on inputs and outputs. The flow model is typically illustrated with a flow chart that includes the activities that are going to be assessed in the relevant supply chain and gives a clear picture of the technical system boundaries. The input and output data needed for the construction of the model are collected for all activities within the system boundary, including from the supply chain.

To ensure the completeness and veracity of the assessment results, the life cycle inventory with all detailed environmental related data is required.

Life cycle impact assessment

Inventory analysis is followed by impact assessment. This phase of LCA is aimed at evaluating the significance of potential environmental impacts based on the LCI flow results. Classical life cycle impact assessment (LCIA) consists of the selected impact categories in previous step.

Interpretation

Life Cycle Interpretation is a systematic technique to identify, quantify, check, show and evaluate information from the results of the life cycle inventory and/or the life cycle impact assessment. The multi-graphic forms are support the results presentation (Matrix table, pie graph, radar graph and histogram etc.) The sensitivity, consistency check and other functions might be launched to complete the conclusion and recommendations.

Environmental targets directly supported by product-oriented LCA

- **Product's life cycle environmental performance calculation (Quantitative)**

The main purpose of this target is to obtain the quantitative results of product's life cycle environmental performance.

- **Product's life cycle environmental performance evaluation**
  The main purpose of this target is to make an environmental life cycle evaluation. Basing on the calculation of life cycle environmental impacts, some methods, such as the sensitivity analysis, the scenario analysis and tracking back analysis, etc., might be used to identify the cause of the environmental impacts, the significant items of product's life cycle and the contribution ratio of each element. Finally, a conclusion and some recommendations of future improvement might be released.

- **Product's life cycle environmental performance improvement**
  The main purpose of this target is to improve the product's life cycle environmental performance by some alternative design activities. This target includes the redesign for actual product and the eco-design for other product basing on the "product's life cycle environmental performance evaluation" of actual product. To achieve this target, an improving objective and some related improvable solution are required. Finally, the LCA software could evaluate the improved product's life cycle environmental performance to measure the improvement.

Action chain of each target supported by product-oriented LCA

Today, with the development of life cycle assessment (LCA) software, most of previous steps, especially, the life cycle inventory and life cycle impact assessment steps, could be totally supported by the pre-defined modules (database) and the embedded calculation methods in the LCA software. The life cycle inventory (LCI) database provides a simple and credible solution to identify the standard flow model and related elementary flow. Thanks to the existing software, the action chain of LCA could be simplified.

Action chain of Product's life cycle environmental performance calculation (Quantitative)

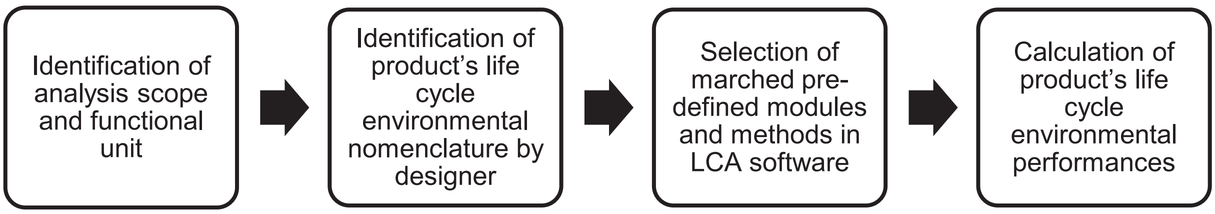


Figure 3: Action chain of target - Product's life cycle environmental performance calculation

Action 1: Identification of analysis scope and functional unit

This action defines which product or product family will be covered by this analysis. According to the scope definition, a functional unit should be specific to pilot the future work.

Inputs/Outputs necessary for this action

Input	Output
Product list	Products list of analysis scope
	Definition of functional unit

Tableau 1: I/O list of action - Identification of analysis scope and functional unit

The competence necessary

- ✓ The knowledge of identification of product family (If need)
- ✓ The knowledge of the functional unit and how to identify the functional unit

Action 2: Identification of product's life cycle environmental nomenclature by designer

The main purpose of this action is to identify all necessary definition to describe the product's life cycle situation. This identification don't need to touch details elementary flow as a standard life cycle inventory, it should complete the information to help the identification of different scenarios. For example, this nomenclature should explicit the end of life treatment scenarios (Reusing, dismantling, shredding, energy recover and landfill, etc.) of each component.

Inputs/Outputs necessary for this action

Input	Output
Definition of functional unit	Products life cycle environmental nomenclature
Product's bill of material	Environmental nomenclature of product's constitution
	Environmental nomenclature of transport/logistics
	Environmental nomenclature of Installation / utilization / Maintenance
	Environmental nomenclature of product's end of life

Tableau 2: I/O list of action - Identification of product's life cycle environmental nomenclature by designer

The competence necessary

- ✓ The knowledge and the data to clearly identify the environmental nomenclature of each phase

Action 3: Selection of marched pre-defined modules and methods in LCA software

According to product's life cycle nomenclature, this action requires to select the most marched pre-defined modules in LCA software to complete the life cycle model. For each selected module, the characteristics should be identified. The life cycle impact assessment method needs to be also identified.

Inputs/Outputs necessary for this action

Input	Output
Products life cycle environmental nomenclature	Selected and characterized modules list in LCA software

Tableau 3: I/O list of action - Selection of marched pre-defined modules and methods in LCA software

The competence necessary

- ✓ The competence to select the closest or the most suited pre-defined modules of LCA software by comparing the product's life cycle environmental nomenclature and the description of each module.
- ✓ Translate the data of nomenclature as the characteristics of each selected module.
- ✓ The knowledge of LCA software utilization
- ✓ If necessary, the knowledge of LCA software to customize the modules and assessment method

Action 4: Calculation of product's life cycle environmental performances

If all necessary modules have been selected and characterized, the LCA software could automatically calculate the life cycle environmental performances.

Inputs/Outputs necessary for this action

Input	Output
Selected and characterized	Product's life cycle environmental performances

modules list in LCA software	*(presented by indicators per life cycle phase)*

Tableau 4: I/O list of action - Calculation of product's life cycle environmental performances

The competence necessary

- ✓ The knowledge of LCA software utilization

Action chain of Product's life cycle environmental performance evaluation

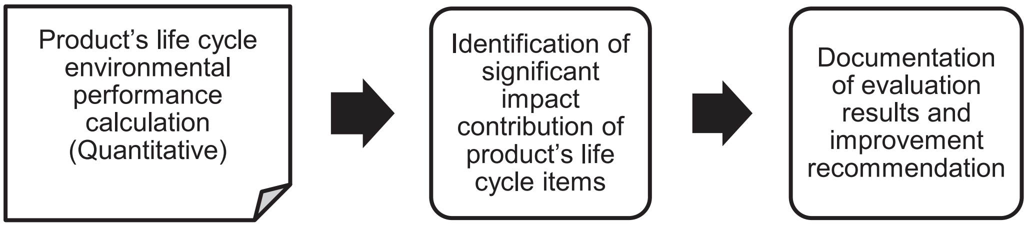


Figure 4: Action chain of target - Product's life cycle environmental performance evaluation

Action 1: Identification of significant impact contribution of product's life cycle items

Basing on the calculation of life cycle environmental impacts, this action requires identifying the cause of the environmental impacts, the significant items of product's life cycle and the contribution ratio of each life cycle element.

Inputs/Outputs necessary for this action

Input	Output
Product's life cycle environmental performances *(presented by indicators per life cycle phase)*	The significant phase of product's life cycle
	The significant element of product's life cycle
	The significant contribution of each indicator

Tableau 5: I/O list of action - Identification of significant impact contribution of product's life cycle items

The competence necessary

- ✓ The knowledge of LCA software utilization
- ✓ Or the knowledge of qualitative/semi-quantitative tools to evaluate the environmental impacts

Action 2: Documentation of evaluation results and improvement recommendation

This action requires a data registration to save the evaluation results.

Inputs/Outputs necessary for this action

Input	Output
The significant phase of product's life cycle	Product's life cycle environmental performance evaluation report
The significant element of product's life cycle	
The significant contribution of each indicator	Improvement recommendation (Optional)

Tableau 6: I/O list of action - Documentation of evaluation results and improvement recommendation

The competence necessary

- ✓ Documentation and knowledge management

Action chain of the target: Product's life cycle environmental performance improvement

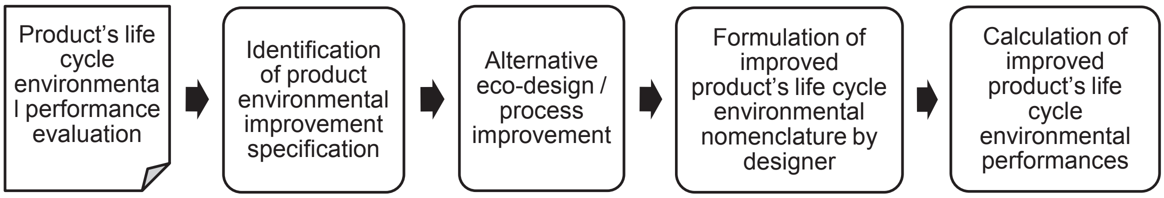


Figure 5: Action chain of target - Product's life cycle environmental performance improvement

Action 1: Identification of product environmental improvement specification

Basing on the evaluation results of actual product's life cycle environmental impacts and some environmental improvement recommendation, this action requires identifying a specification to fix the improvement objectives. This objective includes the final targets of this improvement, the environmental indicators should be considered and the list of related life cycle items will be optimized. The items are not only be caused by product designer, but might be also contributed by the supplier management, the manufacturing process, the logistic network and the end of life management.

Inputs/Outputs necessary for this action

Input	Output
The significant phase of product's life cycle	Product's life cycle environmental improvement specification
The significant element of product's life cycle	
The significant contribution of each indicator	

Tableau 7: I/O list of action - Identification of product environmental improvement specification

The competence necessary

- ✓ The knowledge of LCA software utilization
- ✓ Or the knowledge of qualitative/semi-quantitative tools to evaluate the environmental impacts

Action 2: Alternative eco-design / process improvement

According to the product's environmental improvement specification, the alternative researches will be done to resolve the environmental concerned problems. To resolve these topics, some tools and information are necessary to provide the potential solutions. The LCA software could alternative calculate and verify the new environmental profits of these improvements.

Inputs/Outputs necessary for this action

Input	Output
Product's life cycle environmental improvement specification	Product's eco-design results
	Product's manufacturing improvement
	Product's supplier management improvement
	Product's logistics optimization
	Product's Installation/utilization/Maintenance improvement
	Product's end of life treatment improvement

Tableau 8: I/O list of action - Alternative eco-design / process improvement

The competence necessary

- ✓ The knowledge of life cycle improvement of product
- ✓ The coordination and collaboration channels among different corporate functions

Action 3: Formulation of improved product's life cycle environmental nomenclature by designer

After the alternative eco-design, the product's life cycle profits have been improved. The main purpose of this action is to identify all necessary definition to describe the improved new product's life cycle situation. This identification don't need to touch details elementary flow as a standard life cycle inventory, it should complete the information to help the identification of different scenarios. For example, this nomenclature should explicit the end of life treatment scenarios (Reusing, dismantling, shredding, energy recover and landfill, etc.) of each component. Because of the LCA software might be used to alternative calculate the improvement, the list of selected equivalent modules of LCA software could be provided by this action.

Inputs/Outputs necessary for this action

Input	Output
Product's eco-design results	Improved products life cycle environmental nomenclature
Product's manufacturing improvement	Improved environmental nomenclature of product's constitution
Product's supplier management improvement	Improved environmental nomenclature of transport/logistics
Product's logistics optimization	Improved environmental nomenclature of Installation / utilization / Maintenance
Product's end of life treatment improvement	Improved environmental nomenclature of product's end of life
	Selected and characterized modules list in LCA software for improved product

Tableau 9: I/O list of action - Formulation of improved product's life cycle environmental nomenclature by designer

The competence necessary

- ✓ The knowledge and the data to clearly identify the environmental nomenclature of each phase

Action 4: Calculation of improved product's life cycle environmental performances

If all necessary modules have been selected and characterized, the LCA software could automatically calculate and validate the life cycle environmental performances. If the evaluation of actual product or comparison reference's environmental impacts is based on the qualitative or quantitative approach, the same calculation method has to be used into this action to ensure the final comparison.

Inputs/Outputs necessary for this action

Input	Output
Selected and characterized modules list in LCA software for improved product	Improved product's life cycle environmental performances *(presented by indicators per life cycle phase)*
Improved products life cycle environmental nomenclature	

Tableau 10: I/O list of action - Calculation of product's life cycle environmental performances

The competence necessary

- ✓ The knowledge of LCA software utilization
- ✓ Or the knowledge of qualitative/semi-quantitative tools to evaluate the environmental impacts

LCA software

Till today, there are grand numbers of LCA software developed in the world which are based on the different routes of evaluation and different databases. The following table X presents a list (not limited) of existing LCA software supports the product-oriented life cycle assessment [European, website], [Jönbrink A.K. 2000].

N°	LCA software	Proprietor / Developer	License cost*	Learning duration*	All products*
1	AIST-LCA Tool	AIST Japon	1	2	Y
2	Eco-selector	Granta Design Ltd		2	Y
3	CUMPAN	Hohenheim Universitat/Daimier Benz	3	2	Y
4	Eco-it	Pré consultants	1	1	Y
5	EcoLab	Nordic Port AB	2	2	Y
6	EcoScan	Turtle Bay	1	2	Y
7	EverdEE	ENEA - Italy			Y
8	EIME	CODDE	2	1	N
9	EPID PC-Tool	Danish environmental protection agency	1	3	Y
10	EPS	Assess Eco-strategy Scandinavia AB	2	3	Y
11	Gabi	PE International GmbH	3	4	Y
12	Green-E	Ecointesys			Y
13	LCAiT	Chalmers Industriteknik, Ekologik	2	3	Y
14	JEMAI-LCA Pro	AIST Japon	1	2	Y
15	KCL-ECO	KCL	2	3	Y
16	SimaPro	Pré consultants	2	2	Y
17	LCA Support	NEC corporation	2	2	Y
18	TEAM	Eco bilan	2	2	Y
19	Boustead Model	Boustead consulting	4	2	Y
20	Umberto	ifu Hamburg GmbH	2	3	Y

Note: The license cost code: classify by the number (from 0 to 5) according to a single software license:
Per license (Unit: EURO) per year
0: Free; 1: <1000 €; 2: 1000-5000 €; 3: 5000-10000 €; 4: 10000-20000 €; 5: >20000 €
The duration of learning code: classify by the number (from 0 to 4) according to the official learning times:
1: < 2 hours; 2: < 1 day; 3: < 1 week; 4: < 1 month; 5: Other
All products: classify by the product categories supported by this LCA software:
Y: All product categories supported; N: Certain product categories supported
The information and references are from the official website of LCA software and the report of Sirii -Swedish Industrial Research Institutes Initiative – "LCA software survey", September 2000

Tableau 11: List of LCA software

PCR/FR – Product Category Rules/ Function Rules

To ensure the data quality of environmental declaration and the environmental profits comparison between two similar products/functions, the related environmental analysis and declaration have to comply with the specific and strict methodological prerequisites. So a PCR - Product Category Rules or a FR – Function Rules are vital to be defined before the establishment of product's environmental nomenclatures. The PCR/FR is a standardized document, prepared for one product/function category, which define the rules and some common hypothesis to harmonize the preparation of different environmental nomenclatures and the declaration formula. The following table presents an example of PCR (part) from the association of "PEP Eco Passport".

4. Appendices

4.1.AppendixI:ProductSpecificRules-PSR-forLife Cycle Assessment

4.1.1.Switchgear and control gear solutions and cable management

For this topic, there are three categories of products:

1. Category 1: passive products

   Passive products are located on the electrical power circuit and are crossed by the principal current. They perform functions of contact, opening or conduction in the installation and dissipate energy.

2. Category 2: active products

   Active products are products that perform functions of measurement or energy conversion by consuming the energy on the main electric circuit.

3. Category 3:enclosures

   Enclosures are products and accessories for protection and support of electrical installation materials. They do not consume energy.

4.1.1.1.Typical use scenarios per product category

	Category 1	Category 2	Category 3
Product categories	Passive products	Active products	enclosures
Use life time	20 years	10 years	20 years
Rules for the calculation of consumption / dissipation of energy in the use phase	See category 1 scenario hereinafter	See category 2 scenario hereinafter	See category 3 scenario hereinafter
Examples	Plug and socket outlet, switch, circuit breaker, fuse, equipped envelop. Industrial products, terminals, VDI	Light dimmers, temperature control device, VDI hub, audio video entry,	Path, electrical cabinets, Various accessories,

4.1.1.2. Rules for the calculation of energy consumption / dissipation in the use phase

The rules applicable are different according to the categories of products:

- Category 1: passive product

- Scenario "passive product - non-permanent operation": products crossed by the non-

permanent operating principal current:
  - ✓ rate of load / nominal current (In): 30% of In
  - ✓ Percentage of use time: 30%
- Scenario "passive product-permanent operation": products crossed by the permanent operating principal current:
  - ✓ Rate of load / nominal current (In): 30% of In
  - ✓ Percentage of use time: 100%

▪ Category 2: Active product

Indicate, according to the operating mode(s) of the reference product:
The power consumed for each of the operating mode (off, standby, on, etc…)
The duration of the operating modes as a percentage of a full cycle time.

When they exist, the scenarios for the calculation of energy consumption defined, for a category of product, by a regulation (ErP measure of execution, thermal regulation, energy saving certificates, Ecolabel…) must be taken into account. These elements documented in the LCA report are described in the PEP

For complex operating modes corresponding to varying powers, it is possible to establish average powers by justifying and specifying the calculation assumptions.

▪ Category 3: enclosure

No Energy use in use phase for this product category that represent the enclosures.

Tableau 12: An example of PCR (Source [PEP, 2010])

The PCR/FR has to be attached with the environmental analysis results and the related declaration documents to complete the necessary information.

The PCR/FR could be identified by some international/national standard organization; it allows also each company defines its corporate rules to ensure the comparison between its products/service.

Environmental targets directly supported by PCR/FR

- **Identification of product's life cycle environmental nomenclature by PCR**
  The main purpose of this action is to identify all necessary definition to describe the product's life cycle situation. This identification don't need to touch details elementary flow as a standard life cycle inventory, it should complete the information to help the identification of different scenarios.
- **Identification of function's environmental nomenclature by FR**
  The main purpose of this action is to identify all necessary definition to describe the action chain of function. It should complete all information to help the identification of different scenarios.

Action chain of each environmental target supported by PCR/FR

Action chain of target: Identification of product's life cycle environmental nomenclature by PCR

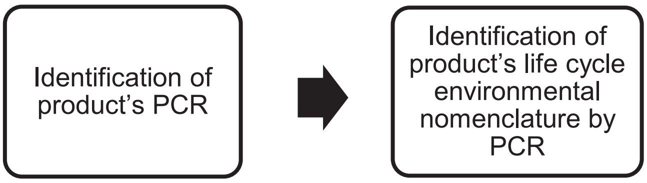


Figure 6: Action chain of target - Identification of product's life cycle environmental nomenclature by PCR

Action 1: Identification of product's PCR

The main purpose of this action is to identify the content of product's PCR. According to the different considered life cycle, the PCR includes the hypothesis and pre-defined scenarios concerned with the life cycle environmental inventory, such as the definition of the frontier of analysis, the elementary flow should be considered and the certain predefined data. This definition can support the designer and company to easily establish the product life cycle environmental nomenclature. The identification of product's PCR could be either consulted by the existing PCR rules, or fulfilled with corporate definition, or both of them.

Inputs/Outputs necessary for this action

Input	Output
Product category	Product category rules – PCR
Corporate requirements	Definition of functional unit

Tableau 13: I/O list of action - Identification of product's PCR

The competence necessary

- ✓ The knowledge of life cycle assessment
- ✓ The knowledge of product (Material, structure, logistics network, production, etc.)

Action 2: Identification of product's life cycle environmental nomenclature by PCR

According to the PCR, The designer fills in all necessary information/data of product's life cycle environmental nomenclature.

Inputs/Outputs necessary for this action

Input	Output
Definition of functional unit	Products life cycle environmental nomenclature
Product's bill of material	Environmental nomenclature of product's constitution
Product category rules - PCR	Environmental nomenclature of transport/logistics
	Environmental nomenclature of Installation / utilization / Maintenance
	Environmental nomenclature of product's end of life

Tableau 14: I/O list of action - Identification of product's life cycle environmental nomenclature by PCR

The competence necessary

- ✓ The knowledge of documentation

Identification of function's environmental nomenclature by FR

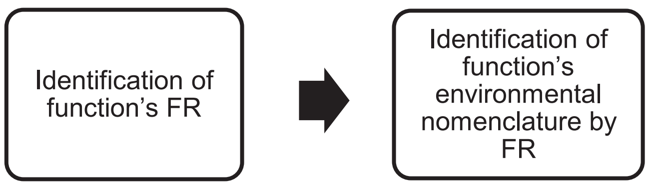


Figure 7: Action chain of target - Identification of function's environmental nomenclature by FR

Action 1: Identification of function's FR

Similar with PCR, The main purpose of this action is to identify the content of function's FR to define the hypothesis, requirements and pre-defined scenarios to prepare function's environmental inventory.

Inputs/Outputs necessary for this action

Input	Output
Function category	Function rules – FR
Corporate requirements	Definition of functional unit

Tableau 15: I/O list of action - Identification of function's FR

The competence necessary

- ✓ The knowledge of life cycle assessment
- ✓ The knowledge of the action chain and related elements of function

Action 2: Identification of function's environmental nomenclature by FR

According to the FR, The designer or production department fills in all necessary information/data of function's environmental nomenclature.

Inputs/Outputs necessary for this action

Input	Output
Definition of functional unit	Function environmental nomenclature
Action chain of function	
Function rules - FR	

Tableau 16: I/O list of action - Identification of function's environmental nomenclature by FR

The competence necessary

- ✓ The knowledge of documentation

PCR/FR References

According to ISO 14025, there are numbers of declaration programs which provide the creditable and comparable PCR for certain product categories. So the identification of product's PCR could be either consulted by the existing rules. The following table X presents a list (not limited) of existing PCR providers.

PCR Provider	Proprietor	Concerned markets	Countries deployment	Cost[1,2]
EPD International	EPD International association	Multi-products/Process[3]	International[4]	Int.70€ Ext.1500€
FDE&S	AFNOR	Construction goods	France	Int. 2275€ Ext. 2275€
Eco-leaf	JEMAI	Multi-products/Process[5]	National (Japan)	Int. 1200€ Ext. 2400€
EDP	KOECO and KEPA	Multi-products	National (South Korea)	?
NHO EPD	NHO and BNL	Process, energy, furniture industries	National (Norway)	?
EPDS	CPPA	Pulp and paper mill	National (Canada)	?
MVD	MVD consortium	Multi-products[6]	National (Denmark)	?
P.E.P.	P.E.P. Association	EEE	Europe/France	Annual fees of company
Note:				

1. *The cost here is the cost to publish a Product Environmental Declaration, is not a fee of PCR purchasing. The first step of declaration is to obtain the PCR, so the cost here might present the equivalent fee of PCR.*
2. *The cost in this table shows as the cost per published declaration. "Int." means the cost for jointed companies of program; "Ext." means the cost for other company. Ex: Int.70€; Ext.1500€.*
3. *242 PCR's have been published: http://www.environdec.com/en/Product-Category-Rules/PCR-Search/?query=**
4. *Till 2009, EPD International PCR have been deployed to Italy, Japan, Sweden, Czech Republic and Germany.*
5. Industrial goods, durable consumer goods, daily necessities, energy such as electricity, buildings, food, and services associated with these products
6. 6 groups of products: electricity and heat, cargo transport, textiles, paper, furniture and windows

Tableau 17: List of existing PCR providers

Product-oriented matrix LCA

The traditional life cycle assessment requires grand numbers of product's life cycle data and an advanced LCA knowledge. For some simplified needs, which don't require the specific data of each environmental indicator, especially in small and medium company, a simplified, qualitative or semi-quantitative matrix approach is necessary. Product-oriented matrix LCA supports this need. As its name, this matrix approach evaluates the product's life cycle environmental performances by using a two-dimension table or matrix. Normally, a dimension of table represents the life cycle of products; another dimension lists the pre-selected environmental indicators. In each cellule of table, an evaluation result, which presents the environmental impacts level in one life cycle phase, have to be filled in by the tool's user.

This matrix approach provides a simplified and fast solution to make the product's LCA. But as all other qualitative and semi-quantitative tools, potential user may have some difficulties to fill it in without the help of an expert, because of the assessment of each impact without quantification and accurate data is relatively subjective and awarding the results [Wong Y.L., 2008], [Janin M, 2000], [Lindahl M, 2006]. And the subjective definition and the inarticulate impacts lead to a difficulty to compare the environmental profiles between two products.

[Yang, 2006] shows that if there is a common rule for score awarding, the Matrix LCA ensure a straightforward, simple and fast comparison between different products. So to improve the creditability and comparability of evaluation results, for a product category, the author proposes a preparatory study to identify these common rules and the recommendations. Some qualitative/semi-quantitative prioritization tools, for example ABC analysis approach, PCR, etc., might support this need.

Environmental targets directly supported by product-oriented matrix LCA

- **Product's life cycle environmental performance calculation (Qualitative/Semi-quantitative)**

  According to the product life cycle environmental nomenclature or inventory, qualitatively or semi-quantitatively the environmental impacts (selected by the pre-defined tools or users) for each life cycle phase.

- **Product's life cycle environmental performance evaluation**
  Noticed in "Product-oriented quantitative LCA" chapter

- **Product's life cycle environmental performance improvement**
  Noticed in "Product-oriented quantitative LCA" chapter

Action chain of each target supported by product-oriented matrix LCA

Action chain of the target: Product's life cycle environmental performance calculation (Qualitative/Semi-quantitative)

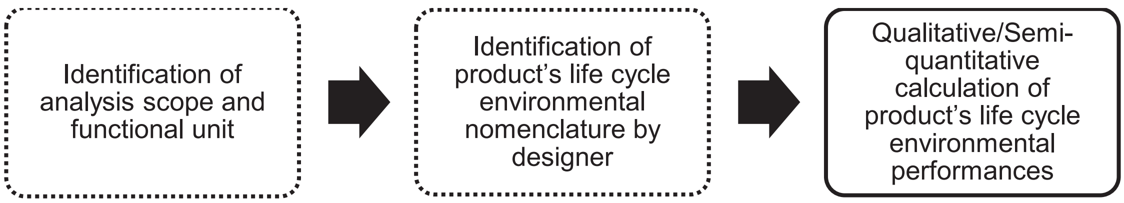


Figure 8: Action chain of target - Product's life cycle environmental performance calculation - (Qualitative/Semi-quantitative)

Action 1: Calculation of Product’s life cycle environmental performance (Qualitative/Semi-quantitative)

Without the support of LCA software, the potential users directly award the environmental impacts of product according to the product’s life cycle environmental nomenclature. If existing, a rule or recommendation of score awarding is a forceful support.

Inputs/Outputs necessary for this action

Input	Output
Product’s life cycle environmental nomenclature	Product’s life cycle environmental performances *(presented by indicators per life cycle phase)*
Score awarding rules (Optional)	Documentation of score awarding rules

Tableau 18: I/O list of action - Calculation of Product’s life cycle environmental performance (Qualitative/Semi-quantitative)

The competence necessary

- ✓ The knowledge of life cycle assessment
- ✓ The knowledge of product life cycle
- ✓ The knowledge of the environmental impact analysis

Product-oriented matrix LCA references

There are several proposed matrix LCA tools. There are some examples shown in following paragraph.

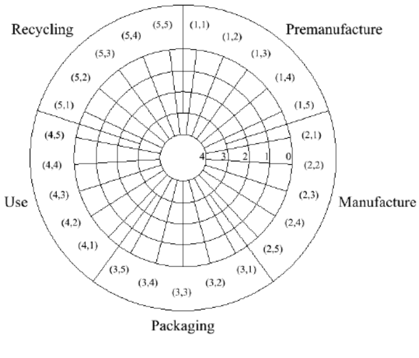
ERPA – Environmentally Responsible Product Assembly Matrix

ERPA, also called AT&T matrix and target plot, is a semi-quantity multi-life cycle assessment method to evaluate the environmental performance of a product. By comparing with other similar items, ERPA could also support to identify which area has the priority to be resolved or improved.

At first, all life cycle of product have been considered: Resource extraction phase, product manufacturing phase, product delivery phase, product use phase and product disposal / recycling phase. The environmental performance of each phase is evaluated by five pre-defined environmental concerned indicators: Materials choice, energy use, solid residues, liquid residues and gaseous residues.

	Materials choice	Energy use	Solid residues	liquid residues	gaseous residues
Resource extraction					
Product manufacturing					
Product delivery					
Product use					
Product disposal/recycling					

Tableau 19: ERPA Matrix



Each cellule of this ERPA matrix (The impact of each the environmental concerned indicator in each life cycle phase) is graded from 0 (highest negative impacts) to 4 (highest positive impacts). The rating of each cellule lies on the environmental contribution of certain items (working fields, technology, process and structure). To ensure the quality of evaluation and the scoring results, the detailed knowledge of product/process and their environmental contribution are required, although the collection of these data is time consuming and difficult [Hochsehorner E., 2003]. [Yang L., 2006] provides a case study to show how the technical proposal affects the rating results of each indicator and the comparison between different technical proposals.

Finally, once the evaluation is done, a single and overall indicator – Environmental responsible product rating ("R_{ERP}") will be calculated by the summary of all scores in ERPA matrix to show the global achievement. Additionally, this ERPA matrix provides also simple graphic radar (shown in right graph) to present the results. The graphic radar likes a “Dart board”. The whole ring is separated by five areas depending on five life cycle phases. In each phase, five sub-areas are defined according to five environmental concerned indicators. Five concentric circles presents the rating results of each indicator, from 0 to 4, fewer environmental impacts, more close to center.

ERPA provides a more systemic and simple solution to evaluate the environmental performance. Therefore, The ERPA matrix tools could only resolve the impact at product level. But the component and material level is excluding of scope.

There is “computer-based” software, named as VerdEE, to support the realization of ERPA. The tool is implemented on a CD-ROM. It includes two main parts:

1) The self assessment procedure (goal and scope definition, inventory, checklist, assessment matrixes, target plot) and a help-on-line system (procedure description, valuation rules, database and case study);
2) The informative part, which includes the background information about environmental and methodological issues.

Target users are environmentally non-expert designers and engineers of SMEs.

Product Life cycle Matrix

This matrix developed by “Motorola” corporation. Similar with ERPA, this matrix considers five life cycle phase of product and it evaluate the environmental impacts by four criteria: The natural resource consummation, the energy consummation, the personal and earth health [Hoffman, 1995]. To evaluate the impacts and award the score, for each cellule, this tool provides 4 questions. If the answer is positive, the score is noticed “1”, which means minimum impacts, inversely, note “0”. As a summary, the final note of each life cycle phase is noted between “0” to “4”, “4” represents the minimum impacts.

MECO – Matrix of Material, Energy, Chemical and Others

Similar with other matrix tools, this MECO matrix considers five life cycle phase of product. The environmental impacts are evaluated by four different indicators: the consummation of materials and energy, the chemicals performances and other aspects which not includes in three previous. The two first aspects, consumption of materials and energy are calculated by the quantitative data. The matrix provides a set of specific classification methods to evaluate the score of “chemicals”. It allows the potential user define the individual criteria for the additional aspects, which is classified in “others” [Hochsehorner, E. 2003], [Wong Y.L., 2009].

		Material	Manufacturing	Use	Disposal	Transport
Material						
	Resource					
	Quantity					
Energy						
	Primary					
	Resource					
Chemical						
Others						

Tableau 20: MECO Matrix

MET Matrix

MET (Materials, Energy, Toxicity) was developed and presented by [Brezet J.C, 1997]. This is a systematic tool in objectivity and reliability to show adequate data of product's environmental impacts [Park P.J. et al., 2006]. The main purpose of this tool is to analyze and prioritize the environmental impacts of product in line with the elementary flow (inputs/outputs) of entire life cycle phase. The elements are classified into three categories: the material flow, the energy flow and the toxic emission flow. To creditably fill in this table, a product's life cycle inventory/nomenclature has to be prepared.

		Material cycle input/ output	Energy use input/output	Toxic emission output/input
Raw material extraction, Processing and Supply of Materials and Components				
Production				
Distribution				
Use	Operation			
	Service			
End of life	Recovery			
	Disposal			

Tableau 21: MET Matrix

Once the table has been filled in, the users have to select some environmental impacts evaluation methods to link with this inventory. As the proposition of [Rodrigo J., 2002], the environmental impacts might be calculate by some typical referential units.

Impacts indicator	Unit
Raw material depletion (RMD)	Year $^{-1}$
Energy depletion (ED)	MJ
Water depletion (WD)	M^3
Global warming potential (GWP)	g of CO_2
Ozone depletion (ODP)	g of CFC-11
Photochemical ozone depletion (POD)	g of C_2H_4
Air acidification (AA)	g of H^+
Air toxicity (AT)	M^3 of bed air
Water toxicity (WT)	M^3 of bad water
Water Eutrophication (WE)	g of PO_4^{3-}
Hazardous waste production (HWP)	Kg

Tableau 22: Environmental indicator calculation [Rodrigo J., 2002]

Finally, the environmental impacts will be classified into three different levels: heavy, medium and light according to the score value.

Product-oriented Check list

Product-oriented check list refer to a list of questions to evaluate the product environmental impacts. This type of tool is widely used to simply capture different product aspects and performances in product planning and development stage for a clear environmental improvement target. This target is set up according to some significant product's life cycle environmental impacts which have been predefined by the tool's proprietor. The tool's potential user answer the questions with the qualitative (Ex: Yes-No) or semi-quantitative (Ex: score 0-10)) score to identify the product's situation. Finally, these evaluation results are valuable to prioritize the environmental improvement tendencies and fix the final specification.

The boundary of the checklist could not only respect life cycle thinking, it might also just cover some specific life cycle phases and some specific environmental impacts.

The technical files of "Environmental declaration" and "Eco label" systems might be considered as a "check list" for certain product's categories. Inversely, these technical files could be extended to check the product's environmental aspects.

Environmental targets directly supported by product-oriented checklist

- **Product's life cycle environmental performance calculation (by checklist)**
  The checklist provides a set of questions to evaluate the product's environmental aspects. By answering these questions, a clear environmental overview of product might be created.
- Product's life cycle environmental performance improvement (by checklist)
  According to the scores of all questions, the improvement specification with the environmental items priority is created. Some alternative rechecks might be done during the development phase to verify the achievement. Finally, an improved result of checklist could be provided.

Actions chain of targets supported by product-oriented checklist

Action chain of the target: Product's life cycle environmental performance calculation (by checklist)

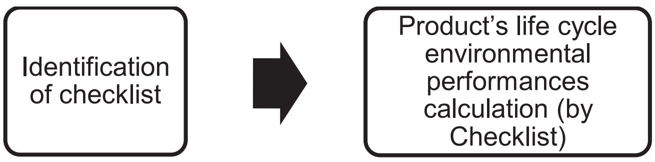


Figure 9: Action chain of target - Product's life cycle environmental performance calculation (by checklist)

Action 1: Identification of checklist

The main purpose of this action is to identify the content of product's check list. According to the different needs, the check list provides the questions list and related answering support (the equation of calculation, the units, the definition of hierarchical levels, etc.) which could cover the entire life cycle phases of product, or just focus on one phase or one environmental impact. The identification of product's checklist could be either consulted by the existing list, or fulfilled with corporate definition, or both of them. The existing list is available from some environmental evaluation tools, the environmental declaration systems, Eco label systems and other company's contribution.

Inputs/Outputs necessary for this action

Input	Output
Product category	Checklist (set of questions and related answering support)
Corporate requirements	
(Optional) Life cycle evaluation results and improvement recommendation	
The existing checklist	

Tableau 23: I/O list of action - Identification of checklist

The competence necessary

- ✓ The knowledge of the relationship between the environmental impacts and product's aspects.
- ✓ The knowledge of product (Material, structure, logistics network, production, etc.)

Action 2: Product's life cycle environmental performance calculation (by checklist)

For each question of checklist, the user identifies the answer with the help from the pre-defined answering supports. The summary of all answer is considered as an environmental evaluation result of this product.

Inputs/Outputs necessary for this action

Input	Output
Checklist template	Checklist with answers and evaluation scores

Tableau 24: I/O list of action - Product's life cycle environmental performance calculation (by checklist)

The competence necessary

- ✓ The knowledge of product

Action chain of the target: Product's life cycle environmental performance improvement (by checklist)

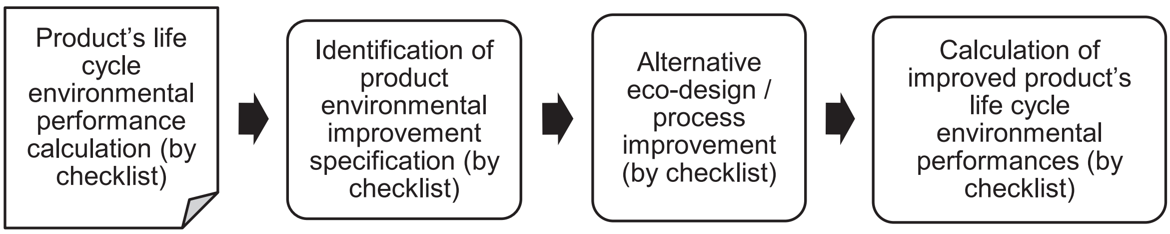


Figure 10: Action chain of target - Product's life cycle environmental performance calculation (by checklist)

Action 1: Identification of product environmental improvement specification (by checklist)

The checklist provides a simple solution to show which environmental items should be improved. According to the product's evaluation results, all negative answers of mandatory questions should be listed in the product's specification which defines the improvement targets.

Inputs/Outputs necessary for this action

Input	Output
Checklist (set of questions and related answering support)	Product's life cycle environmental improvement specification (by checklist)

Tableau 25: I/O list of action - Identification of product environmental improvement specification (by checklist)

The competence necessary

- ✓ The knowledge of documentation

Action 2: Alternative eco-design / process improvement (by checklist)

According to the product's environmental improvement specification (by checklist), the alternative researches will be done to resolve the environmental concerned problems. To resolve these topics, some tools and information are necessary to provide the potential solutions. The checklist could alternative verify the new environmental profits of these improvements.

Inputs/Outputs necessary for this action

Input	Output
Product's life cycle environmental improvement specification (by checklist)	Product's eco-design results
	Product's manufacturing improvement
	Product's supplier management improvement
	Product's logistics optimization
	Product's Installation/utilization/Maintenance improvement
	Product's end of life treatment improvement

Tableau 26: I/O list of action - Alternative eco-design / process improvement by checklist

The competence necessary

- ✓ The knowledge of life cycle improvement of product
- ✓ The coordination and collaboration channels among different corporate functions

Action 3: Calculation of improved product's life cycle environmental performances (by checklist)

Finally, the checklist is reused to validate the final achievement of the new improved product.

Inputs/Outputs necessary for this action

Input	Output
Product's eco design results	Checklist with improved answers and evaluation scores
Product's manufacturing improvement	
Product's supplier management improvement	
Product's logistics optimization	
Product's Installation/utilization/Maintenance improvement	
Product's end of life treatment improvement	

Tableau 27: I/O list of action - Calculation of improved product's life cycle environmental performances (by checklist)

The competence necessary

- ✓ Documentation

Product-oriented checklist references

The checklist is a common and simple tool to support the environmental consideration. Several existing different types of checklist are available could be referred. According to the checklist requirements, there are the comparative checklists, which evaluate the score by comparing with reference product, and the endorsement checklists, which provide the threshold to each answer. According to the criteria, there are entire life cycle checklist, multi-criteria checklist and mono-criterion checklist. Depending on the different proprietors, the checklist might come from the eco label system, environmental declaration system, the formulated environmental tools and the company's program. Some examples are shown as follow:

Tool's name	Description	Reference
DFE Matrix	100 questions cover the whole life cycle The rating system ling on the answers	Explanation of Product DfE Matrix[1]
Notes: 1. *The document is available on website* *http://ritsustainabilitydesigncolab.files.wordpress.com/2010/10/explanation-of-product-dfe-matrix1.pdf*		

Tableau 28: Summary table of checklist

"Fast Five" Checklist

"Fast five" checklist is a qualitative approach that has been developed by Philips Corporation. It is a quick check list to analyze the concepts of a new product comparing with a reference product. To complete a "fast five" checklist, users need to answer questions with yes/no in five categories: energy, recyclability, hazardous waste content, durability, reparability and preciousness and alternative ways to provide service.

Category	Question	Yes	No
Energy	Does the proposed design require less energy than the reference product? (consider manufacturing, transportation, product use)		
Recyclability	Is the proposed product more recyclable than the reference product? - Separation of large components/ assemblies into mono-material subassemblies - Amount of actually recyclable materials in the product		
Hazardous waste content	Does the product design contain and/or produce less chemical waste than the reference product design? - Any restricted materials such as halogenated flame retardants, cadmium pigments, or ozone depleting chemicals (ODSC)		
Durability, reparability and preciousness	Does the proposed design have better durability, reparability or affection level than the reference product? - New design last longer and easier to upgrade? - Will the precious quality of new product make the user/owner keep the product longer?		
Alternative ways to provide service	Are there ways to provide that produces lower ecological load? - Techniques that require lower energy/material but provide the same service or quality.		

Tableau 29: The "Fast Five" checklist

Once the user complete this list by filling in the "Yes" or "No", a simple judgment of this new technical proposition will be interpreted based on the follow table. More "Yes" means better concept. If there are five "Yes" in the table, it means that this technical proposition is excellent. But if just one "Yes" appears, the proposition should be re-considered and re-designed.

When practitioners complete the checklist by filling "yes" or "no", interpretation about the assessed product can be concluded based on table X. The number of time for answering "yes" is counted according to the overall results of each category. When "yes" appeared three times, the product is considered to be an interesting alternative but still have a space for improvement. If the answer is "yes" only one time, the product should be upgraded to the reference product. Therefore, the product would be better if more "yes" appear.

No. of "Yes"	Result interpretation
0	Where is your 'green' feeling?

1	Upgrade the reference.
2	Pleases reconsider the reference concept.
3	Interesting alternative, but where still to improve.
4	Probably a viable choice.
5	An excellent alternative.

Tableau 30: Result interpretations of "fast five" checklist

Eco-estimator

Eco-estimator is a multiple criteria checklist developed by Philips Corporation, concerns about the electrical and electronic products. This checklist evaluates the environmental impacts in terms of questions about the product life, the energy and material using, the recyclability and the hazardous waste. For each question, the calculation equation, the unit and the methods to identify the score is provided. Finally, a total score of product is calculated, low value means low environmental impacts.

Worksheet for eco-estimator (Parts)

Product Name					
Responsible person		Date			
	Question	Equation	Value	Unit	Remarks
A) product Life					
1a	How many years is this type of product used?	---		Years	---
1b	Does easy repair increase the number of years of use?	---		Years	Add on the number of years
1c	Does upgradeability increase the number of years of use?	---		Years	Add on the number of years
	Total product life (A)	1a+1b+1c		Years	---
B) Energy and material					
2a	2a) How many watts of electricity does it use per hour in normal mode? (If energy efficiency decreases as product ages, average efficiency over product life is used)	---		W	---
2b	How many hours is it used per year in normal mode? (Hours per day multiplied by days per year)	---		h/y	---
2c	How many kilowatt hours per year in normal mode?	2ax2b/1000		kw˙h/y	---
……………..					
C) Recyclability					
3a	Are the housing and other large parts easily separated into mono-material pieces? (If final plastics are to be mixed, plastic compatibility is regarded)	---		---	Yes = 0 Somewhat = 1 No = 2
3b	Are metal parts easily separable from each other? (Can parts heavier than 100 grams be separated into mono-material fractions?)	---		---	Yes = 0 Somewhat = 1 No = 2
3c	Are non-recyclable elements used with plastic: non-recyclable flame retardants, paper stickers on plastic parts, or non-recyclable adhesive? (Consider parts	---		---	Yes = 1 No = 0

	heavier than 100 grams)				
3a	Are the housing and other large parts easily separated into mono-material pieces? (If final plastics are to be mixed, plastic compatibility is regarded)	---		---	Yes = 0 Somewhat = 1 No = 2
3b	Are metal parts easily separable from each other? (Can parts heavier than 100 grams are separated into mono-material fractions?)	---		---	Yes = 0 Somewhat = 1 No = 2
3c	Are non-recyclable elements used with plastic: non-recyclable flame retardants, paper stickers on plastic parts, or non-recyclable adhesive? (Consider parts heavier than 100 grams)	---		---	Yes = 1 No = 0
………………					
4) Hazardous waste					
4a	Product contains one or more banned substances according to law and company policy.	---		---	Yes = 400 No = 0
4b	The product uses batteries. (if not, go to 4c) i. It only has small batteries for emergency back-up power. ii. It uses rechargeable batteries which are recharged inside the product. iii. It uses rechargeable batteries which are recharged outside the product. iv. It uses either rechargeable or non-rechargeable batteries. v. It cannot use rechargeable product. vi. Battery disposal text or symbol is printed/embossed on the product. vii. Battery disposal text or symbol is not printed/embossed on the product.	---		---	No = 0 i. Yes = 15 ii. Yes = 30 iii. Yes = 40 iv. Yes = 120 v. Yes = 200 vi. Yes = 0 vii. Yes = 100
4c	Is polyvinyl chloride (PVC) used, including cable or packaging?	---		---	Yes = 40 No = 0
4d	Are the printed circuit boards and electronics on easily removable modules? (Can the electronics be simply and quickly removed from the product?	---		---	Yes = 40 No = 0
	Hazardous waste total (Subtotal D):	4a+4b+4c +4d		---	---
	Eco-estimator total	B+C+D		---	---
	Eco-estimator per Year	(B+C+D)/A		Year	---

Tableau 31: Worksheet of “Eco Evaluator” (Part)

Product-oriented Eco label

Eco label is a basic communication tool to declare and promote the product's environmental profiles to customers. By providing the verifiable and accurate information on environmental aspects of products and services, the final objective of "Eco label" system is to affect the final customer's purchasing decision which encourages a less environmental consideration, thereby stimulating the potential for market-driven continuous environmental improvement [GEN, Introduction to eco labelling].

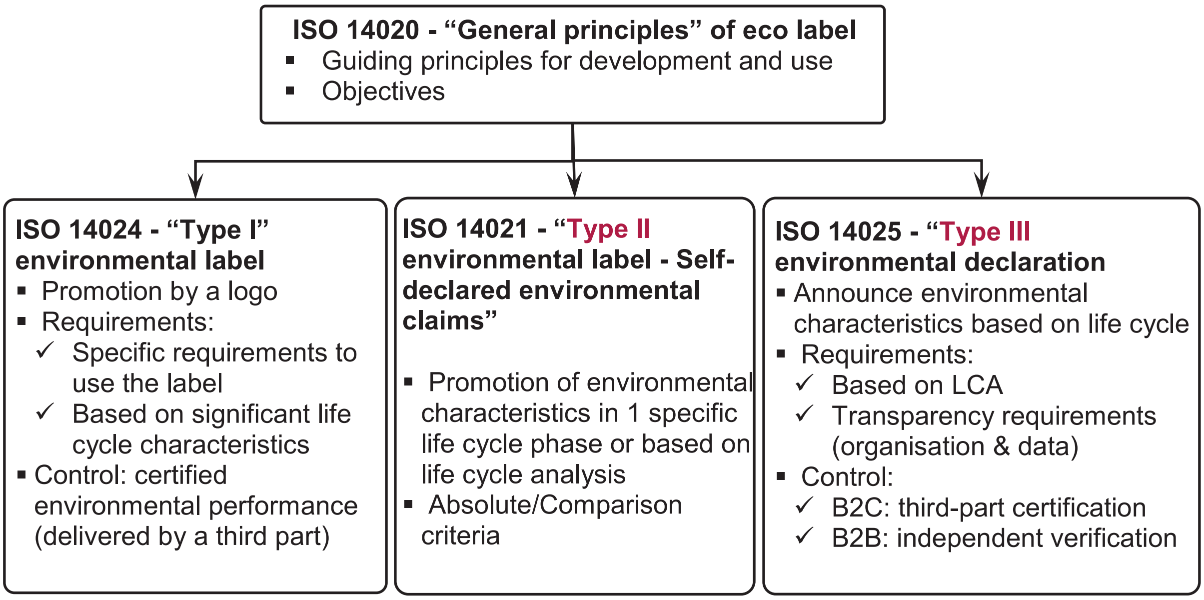


Figure 11: The ISO structure of type I, type II and type III eco label

According to [ISO 14020, 2000] series, there are three different types of eco labelling systems: Type I eco label, Type II eco label and type III eco label.

The type I Eco label [ISO 14024, 1999], is considered as ""A voluntary, multiple-criteria based, third party program that awards a license which authorizes the use of environmental labels on products indicating overall environmental preferability of a product within a product category based on life cycle assessment" [GEN, 2010].

At first, the product/service should fulfill the product criteria defined by third party which include a set of quantitative and qualitative technical requirements on this product's category. To obtain the authorization of "label using", the product/service providers must pass a certification and licensing process and pay the related fee. The re-audit and continuously monitoring process are required also to prolong the labelling duration.

Awareness points

- Label is certified by third parts – avoid the justice problem
- The professional institute or government background organization – avoid creditable problem
- Great promotion by government – avoid awareness problem

But

- There are too many labels. Each label is just available in his country. This situation is inconvenient for international companies.
- Criteria are similar, but not identical. Each label has his special threshold values or description form. It's very difficult to guide the design in face to multi-objective scenarios.

- Criteria establishment and revision is difficult to monitor, not synchronized. For companies, could not have enough times and without the direction to prepare.
- Some eco labels are very expensive.
- Certification process is slow.

Although this type I label has some disadvantages, incontestable, it plays an important role in the world for protecting environment and guiding the direction of design. These threshold values of each environmental performance are defined by third parts which fully consults the opinions from manufacturer, the industrial association and other stakeholders. These criteria always show the top level of actual technology due to in theory, the type I eco label just awards to top 30% products of each category. The type I eco label's criteria are also consulted by other environmental standards. So the check points and criteria of each label could help the company to define the corporate environmental targets and set up the related criteria.

Type II Eco label [ISO 14021, 1999] is defined by ISO as an "Informative environmental self-declaration claims" established by the manufacturers, importers or distributors of product/service. The label system requires neither the external certification, nor the LCA consideration. Because of these flexible characteristics, the Eco label owners could set up some corporate requirements. The comparative requirement is allowed which doesn't set up the absolute threshold (Pass/Failed criteria) for each environmental impacts, it just compares the product with other references, and the companies award the eco label if the advantage (follow the criteria) exist.

Type III Eco label [ISO 14045, 2006] is a quantified product information file based upon independent verification using preset indices. The preset indices define a menu of a product's environmental impacts should be declared throughout its life cycle. To prepare the data of these indices, the LCA approach is necessary.

The indices categories and the evaluation criteria can be set by industrial sector or by independent bodies. Unlike Type I labels, they do not judge the products. The idea is to provide common environmental performance indicators (EPI) system and the evaluation methods to compile the environmental score for each product that consumers could use to compare different goods.

However, there are some specific "eco label" systems, organized by no-profits or profits program, exclude in these three types. These labels are either focusing on certain products or not restricted to LCA approach. But the structure of the labelling process is similar with type I eco label, the different is just the content and perimeter definition of technical criteria (named as the streamlined criteria). So in next chapters, the achieving process of this type of eco label is classified into "Type I" eco label system.

Environmental targets directly supported by product-oriented Eco label

- **Product's environmental performance communication by Type I eco label**
- **Product's environmental performance communication by Type II eco label**
  The type II eco label is judged by the corporate self-checklist. The process of environmental improvement by checklist could see in chapter of "Product-oriented" checklist.
- **Product's environmental performance declaration**
  According to the declaration formula, regroup and transfer the environmental evaluation data to the communicable data.

Actions chain of targets supported by product-oriented Eco label

Action chain of the target: Product's environmental performance communication by type I eco label

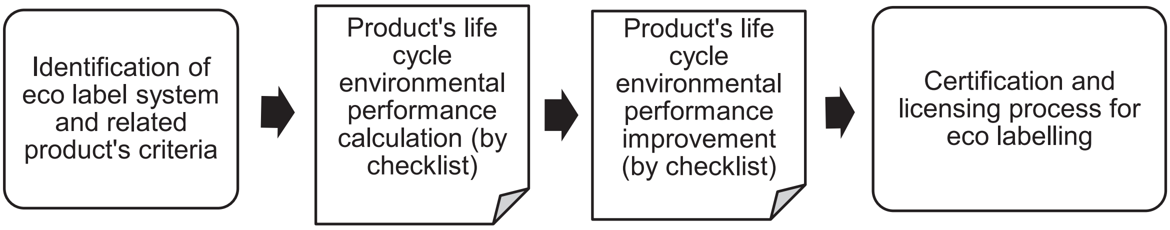


Figure 12: Action chain of target - Product’s environmental performance communication by type I eco label

Action 1: Identification of eco label system and related product's criteria

The main purpose of this action is to identify which eco label system will be asked. According to the selected eco label system, the related judgment criteria of this product could be obtained.

Inputs/Outputs necessary for this action

Input	Output
Product category	Criteria of eco labelling
Product marketing geography	
Analysis of eco label	

Tableau 32: I/O list of action - Identification of eco label system and related product's criteria

The competence necessary

- ✓ The knowledge of product’s category
- ✓ The knowledge of product marketing geography
- ✓ The knowledge of eco label (influence, fee, process of certification, etc.)

Action 2: Certification and licensing process for eco labelling

Once the fulfilling of all criteria, the product/service providers should follow the certification and licensing process to obtain the authorization of label using. This authorization comes from the external third party.

Inputs/Outputs necessary for this action

Input	Output
Checklist with improved answers and evaluation scores	Labelling of product
Certification and licensing process	

Tableau 33: I/O list of action - Certification and licensing process for eco labelling

The competence necessary

- ✓ The knowledge of coordination with external part

Action chain of the target: Product’s environmental performance declaration

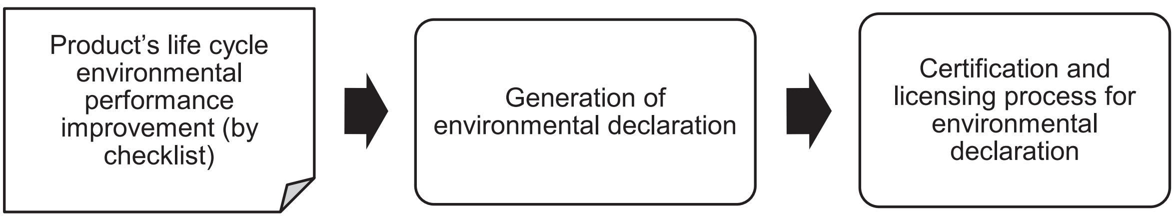


Figure 13: Action chain of target - Product's environmental performance declaration

Action 1: Generation of environmental declaration

Once the fulfilling of all criteria, the product/service providers should follow the certification and licensing process to obtain the authorization of label using. The authorization comes from the internal corporate program management group.

Inputs/Outputs necessary for this action

Input	Output
Improved product's life cycle environmental performances	Product's environmental declaration file
Improved product's life cycle environmental performances (by checklist) - optional	
Formula of declaration file	

Tableau 34: The I/O list of action - Generation of environmental declaration

The competence necessary

- ✓ The knowledge of documentation

Action 2: Certification and licensing process for environmental declaration

Once the fulfilling of all criteria, the product/service providers should follow the certification and licensing process to obtain the authorization of label using. According to different labelling system, the authorization comes from the external third party, or the internal corporate program management group.

Inputs/Outputs necessary for this action

Input	Output
Product's environmental declaration file	Publish of product's environmental declaration
Certification and licensing process	

Tableau 35: The I/O list of action - Certification and licensing process for environmental declaration

The competence necessary

- ✓ The knowledge of coordination among different corporate functions or external party

Product-oriented Eco label

Today, in worldwide, there are 433 "eco label" systems have been developed [Eco label index, website]. A grand number of labelling systems cover the product's certification. According to GEN – Global Eco labelling network, the worldwide official organization of "type I" eco label, there are 27 countries and 31 "Type I" eco label systems. The next following table synthesizes the dashboard of existing 21 "type I" Eco labels [GEN annual report, 2010].

Name	Introduced	Area	Categories	Products Awarded Label
Environmental Choice	1988	Canada	70	10.000
EU flower	1992	EU	26	25.000
Blue Angle	1977	Germany	93	11.995
Swan	1989	Nordic	65	6.000
Eco mark	1989	Japan	47	4.904

Green Seal	1990	U.S.A	30	3.550
Environmental Choice	2001	Australia	41	2200
China Type I	1994	China	81	40.000
Eco Label	1992	Korea	148	8.012
Environmental Marque	1991	France	23	1305
TCO	1980	Sweden	10	1587
Singapore Green Label	1992	Singapore	66	936
Green mark	1992	Taiwan	112	6.000
Green Label	2000	Hong Kong	60	557
Medio Ambiente	1993	Spain	11	436
Environmental Label	1993	Croatia	25	6
Environmental Friendly Products Eco label	1994	Czech	64	192
Environmental Choice	1992	New Zealand	34	2.000
Vitality leaf	2001	Russia	12	12
Green Choice Philippines	2003	Philippines	36	20
Green Label	1994	Thailand	48	461

Tableau 36: A general look of “Type I” Eco label (Source: Annual report 2010 of GEN)

The Eco label system provides the checklist for each product’s category. The follow table summarizes which environmental items have been focused on by each checklist of textile-concerned products. This table mixes the type I, type II and other type of eco label. Normally, all eco label system requires the multi-environmental impacts during the entire life cycle of product. The dangerous material, the production pollution, the package requirement, the utilization information and the recycling rate present the higher priority. Additional, there are three eco label systems require the quantitative LCA to complete the environmental profiles.

Name		Textile						Material & Fabrication methods											Production process								Tran.		Using phase					Rec.	
Name	Nature	Clothes	Textil toyes	Industrial textile	Towel	Shoes	LCA	Dangerous	Colorants	Rot resistance	Flamme	bleached	Dye	Shrink	filling	Metal	Odour	PH	Humain right	Traceability system	Emission	Resource	Production pollution	Energy mgt	Supplier control	CO2	Package	Pesticide in transport	Information	Dimension Changes	Colour fastness	Using time	water used	Recycling rate	Recycling system
ABNT Ecolabel - Brazil	N																																		
AIAB Bio Fibre - Italy	N																																		
Blue Angel - Germany	N	X	X					X	X		X		X				X										X		X		X				
Carbon Reduction Label - England	N																									X									
Environmental Labelling -China	N	X	X					X	X	X	X		X				X	X					X								X				
Climatop - Switzerland	N	X	X				X												X				X			X									
Cradle to Cradle Certification - Germany	P	X	X				X	X														X	X												
Degree of Green - America	P																																		
eco-INSTITUT - Germany	P	X						X									X				X														
Ecomark - India	N	X						X			X							X									X								
EcoMark - Japan	N	X		X				X	X		X	X										X	X				X								
Environmental Choice - New zealand	N	X					X	X	X		X	X	X	X	X								X	X	X				X	X	X			X	
Environmentally Friendly Product - Czech	N	X						X			X	X	X	X	X	X							X	X					X	X	X		X		
Ecolabel - EU	I	X						X			X	X	X	X	X	X							X	X					X	X	X		X		
FairWertung - Germany	N	X																																X	X
Global Organic Textile Standard - USA	I	X						X	X		X	X	X	X	X								X												
Good Environmental Choice - Australia	N	X						X			X		X		X								X				X	X		X	X				
Green Mark - Taiwan	N	X						X					X																			X			
Green Shape - France	P	X											X									X													
Green Label - Hong Kong	N	X						X	X			X	X	X								X	X				X	X						X	
Nike Considered Design - USA	P	X				X		X														X	X								X			X	X
Ecolabel or "Swan" - Nordic	I	X						X			X	X	X	X	X	X			X				X	X	X				X	X	X		X		X
Oeko-Tex Standard 100 - Switzerland	I	X	X	X	X			X	X	X	X	X	X	X		X	X	X			X														
Processed Chlorine Free - Canada	A				X			X												X			X	X			X		X					X	X
Green Home Green Check - USA	A				X			X													X		X	X					X						
Green Label Scheme - Singapore	N							X	X				X										X						X					X	
SustentaX - Brazil	P																																		
Green Label - Thailand	N	X						X				X	X			X											X				X				
Timberland Green Index - USA	P	X				X		X														X	X			X									

Note 1: The code of eco labelling nature: N – National label; I – International label; P – Label system of profits organization; A – Label of industrial association

Tableau 37: The dashboard of textile-concerned eco labelling system – the checklist with required environmental items

Environmental items prioritization

The development of eco design generates number of available actions which have been established to answer the special attends of product's development. In order to answer the external requirements from government, customers and localization needs, the suitable eco design action or actions group should be prioritized and identified from the complex context and some operational conditions, such as the product's strategic position, the technical capacity and implementation situation etc. Secondly, the designer needs to know the relationship and conflicts between the environmental actions and the product's technical characteristics. These relationships could help the identification of working targets (Ex: the eco-design on product's structure, on component constitution, on function of product, etc.). And then, they should analyze and compare the difficulty, the environmental gains and the technical conflicts between different solutions to make more efficient for development process.

The environmental items prioritization tools are developed to resolve these above two needs. But, the success of these tools strongly depends on the completeness of experience and data on previous working for similar product or the capacity of common knowledge integration. The environmental expertise is normally required.

Environmental targets directly supported by Environmental items prioritization

- **Product's environmental items prioritization**

Actions chain of targets supported by Environmental items prioritization

The action chain of the target: Product's environmental items prioritization

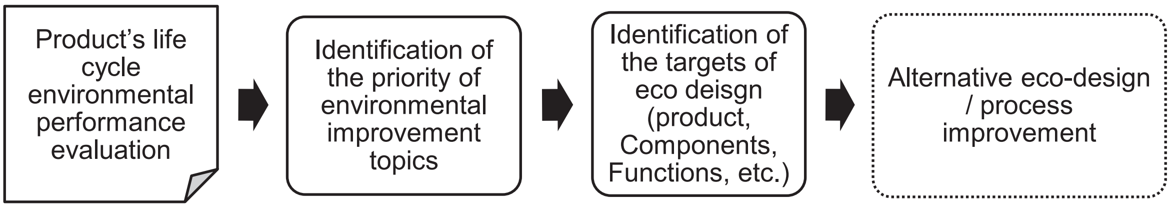


Figure 14: Action chain of target - Product's environmental items prioritization

Action 1: Identification of the priority of environmental improvement topics

Facing to the environmental evaluation results, this action asks the users should identify the priority of all improvable environmental items, such as, certain topics should be prioritized considered, and certain topics could be revolved later. The criteria to identify this priority lie on the operational conditions (The timing pressure, the cost limit, etc.) and the external requirements (marketing attends, the corporate objective, etc.)

Inputs/Outputs necessary for this action

Input	Output
"Product's life cycle environmental performance evaluation report" or "checklist"	The priority of environmental topics
Improvement recommendation (Optional)	

Tableau 38: I/O list of action - Identification of the priority of environmental improvement topics

The competence necessary

- ✓ The knowledge of operational management

Action 2: Identification of the targets of eco design (Product, component, function, etc.)

For each prioritized product's environmental topic, the designer should pre-define which parts and items of product should be designed to hit this topic. The functional redesign, the product structure design, the component design and the related process design, these four different levels of design might be considered and selected. Deeply, the difficulty, the environmental gains and the technical conflicts between different solutions have to be considered in order to find out the best innovation.

Inputs/Outputs necessary for this action

Input	Output
The priority of environmental topics	Product's life cycle environmental improvement specification
"Product's life cycle environmental performance evaluation report" or "checklist"	
Improvement recommendation (Optional)	

Tableau 39: I/O list of action - Identification of the targets of eco design

The competence necessary

- ✓ The knowledge of product
- ✓ The knowledge of the environmental impacts and related causes

Environmental items prioritization references

Tool's name	Comment	Reference
ABC Analysis	Common tool – All use	Shown as below
EFMEA	Common tool – All use	Shown as below
ECA Normalization	Common tool – All use	Shown as below
QFD-Based tools	Common tool – All use	Shown as below
Emission evaluation	Emission benefits and Implementing difficulties	[Bocken N.M.P., 2012]

Tableau 40: Summary table of Existing Environmental items prioritization tools

ABC Analysis

ABC analysis is a straight, simple, qualitative and comparative method to distinguishing the most important elements (such as the activities, processes, products, substances or treatment scenarios) from all other unimportant ones. The distinction or the classification of the importance (or prioritization) is based on the relative assignment of elements which is presented in three classes – class A, B and C, from highest importance to lowest. To make this classification or distinction, a common list of checking issues (or specific criteria) should be pre-defined.

- Class A: Very importance / Very problematic → Highest requirement for an action
- Class B: Importance / problematic → medium-term requirement for an action
- Class C: Low importance / low problematic → no requirement for an action

As a no-specific method, ABC analysis could be used to make the environmental priority decision for all stages of product life cycle phase. According to different application field, such as the project planning or technical decision, the results of the ABC analysis directly support the formulation of different decision. At product planning level, the ABC analysis provides a simple result to distingue the prior action (Ex: environmental improvement by design or by manufacturing, etc.) to resolve the environmental targets, according to external requirements (Ex: the needs of customers, the competitors, the legislation, etc.) and some internal conditions (Ex: the knowledge, the cost, the sources and corporate needs, etc.). At technical decision level, ABC analysis might be used also to evaluate or regroup the priority of different technical proposes.

	Recyclability	Disposal	Product use	Processing	Pre-production	Accident risks	Social acceptance	Legal framework
Ferrous metals	C	C	C	C	B	C	C	C
Alu. sections	C	C	C	C	B	C	B	C
Polyamide	B	B	C	C	A	C	B	C
Polypropylene	C	B	C	C	B	C	C	C
Polyurethane	B	A	C	C	A	A	B	C
PVC	C	A	C	C	A	A	A	C
Polyester	B	B	X	X	A	C	B	C
Latex foam	C	C	C	C	B	C	C	C
Chipboard	B	B	C	B	B	C	B	0

Note: *Assessment according to several ecological criteria (Priority: A → High; B → Medium; C → Low; 0 → Not relevant)*

A (High priority)	Polyurethane PVC
B (Medium priority)	Polyamide Polypropylene Polyester Chipboard
C (Low priority)	Aluminum sections Ferrous metals Latex foam

Note: *Assessment by ecological criterion "Disposal"*

Figure 15: Example of ABC analysis

The comparable elements and evaluable criteria are individual identified by each company. The quality of results lies on the completeness of possible elements and the quality of criteria. So the environmental expert (if exist) might be involved into the preparatory phase to provide a more professional list. To ensure the meaningful classification (to avoid all possible elements are classified in "A" class), some additional condition to limit the percentage of class A or B might be also identified.

There is an extrapolated version of ABC analysis – "ABC-XYZ analysis" which could extend the evaluated to multi-working fields or timing phases. Typically, the "XYZ" might present different duration of sustainable impacts (X – permanent; Y – Temporary; Z - sporadic) or different quantity effect (X – grand quantity effect; Y – medium quantity effect; Z – small quantity effect) Source spécifiée non valide..

A similar tool, named as "La grill d'évaluation", was created by ADEME which supports the qualitative and quantitative analysis of environmental aspects [Janin, 2002]. Finally, the results of analysis are transferred as the three notices: "X" means the prioritized aspects; "-" means the negligible aspects or less impact aspects; and "?" means the lack of necessary data and elements to answer this aspect.

EFMEA

Environmental FMFA, referred also as Environmental Effect Analysis (EEA), is the application of traditional Failure Mode Effect Analysis in the environmental domain. The final objective of this tool is to identify potential environmental impacts and associated improvement causes and objectives based on the past experiences with similar products or processes. The common environmental items are also considered. The score rating and the prioritization system ensure the continuously follow up the achievement during the entire product development process.

For each potential environmental item, the EFMEA provides three indicators to evaluate the "Risk Priority Number" [4Automotive, Website]:

- Occurrence: evaluate the cause of an environmental item and the number of times it occurs. A critical criterion is to account how many pieces cause to this environmental items.
- Severity: determine the gravity of environmental items based on the function unit and effects. The non-compliance of legislation is

- Detection: ranks the ability of tests and inspections to remove defects or detect environmental items in time to avoid the "escape detection". So the disposability of environmental testing methods for certain items is the key factor.

Finally, the "Risk Priority Number - RPN" is calculated as: RPN = O*S*D. according to the order of RPN score, the tool user might identify the product's improvement specification at the beginning of the development and follow the achievement during the entire process by the movement of score.

ECA Normalization

"Environmental Concerned Action Normalization" was published by [Zhang F., 2011]. This is a FMEA-based method to prioritize the environmental items of products. But the feature of this method is the consideration and a more clear description of the "ECA" operational situation into the decision process. Extending the traditional FMEA method, this normalization provides 3 pairs-indicators that are grouped into two classes.

- Class One: External score:
  - ✓ Indicator G - "gravity": This indicator is defined to demonstrate the importance to implement ECAs which affect the pressure of certain ECA for marketing entering. For example, the percentage of offers which should answer the ECA, or when this ECA will become mandatory, etc. For some MCAs, this indicator could also be described as the percentage of customers who ask for this action. According to this, the performance is graded by 10 hierarchical levels, from 1 to 10: a higher score for a more important ECA.
  - ✓ Indicator F - "feasibility": This indicator is defined to demonstrate that the implementation of ECAs is feasible. The level of this indicator depends on the cost, the information needed, the technical capacity, etc. It also considers if the technology is available in other enterprises or at the average level of large-scale industrialization. As for the previous indicator, the performance is graded and summarized by 10 hierarchical levels, from 1 to 10: a higher score for a more feasible ECA.
  - ✓ Indicator V - "visibility": Environmental concerns Actions have been integrated into promotion activities to build the green image of enterprise. This indicator is defined to assess the popularity of ECAs. The "visibility" grades the marketing and public awareness level of certain actions including the execution of the directives, laws, potential innovation, competitive promotion etc. the performance
- Class Two: Internal score:
  - ✓ Indicator A - "achievement": This indicator is defined to demonstrate the level of achievement of environmental concerns action. For example, Percentage of products has been fulfilled for this ECA, etc. To work with previous indicator, the achievement level was also graded by 10 hierarchical levels, from 1 to 10: a higher score is given for a high level of achievement.
  - ✓ Indicator I - "Implementability": This indicator is defined to demonstrate the ability of the enterprise to implement the ECAs inside the enterprise. This indicator evaluate whether the actual organization, supply chain, technical competences and the management process could be helpful to achieve the objective. It also analyzes the relevant cost, risks etc. in a global view. As for the previous indicators, the achievement level is also graded by 10 hierarchical levels, from 1 to 10: A higher score is given for a more implementable ECA
  - ✓ Indicator C – "communication": This indicator is defined to demonstrate the communication level of environmental concerns action. "The great design is always not good enough". This indicator evaluate whether the achievement of such environmental concerns action has been promoted to the public. It also analyzes the communication performance compared to competitors. As for all the other indicators, the achievement level is graded by 10 hierarchical levels, from 1 to 10: A higher score is given for a more visible ECA

These above 6 indicators are also classified in three pairs. The "Gravity" is in pair with achievement"; "feasibility" corresponds with "implmentability"; and the "visible" corresponds with "communication". Each "ECA"- Environmental Concerned Action has to be evaluated with these 6 indicators. Then, a simple multiplication of the scores (G*F*V) is considered to obtain a global external score for the "external" requirements of ECAs and a similar score (A*I*C) is for "internal" situation of ECAs.

According to the comparison of each ECA's scores, a product's improvement recommendation can be identified. The general criterion to make decision depends on the priority indicator (P):

$$Priority\ Indicator\ (P) = Global\ Score_{external} - Global\ Score_{internal}$$

If it exists a visible positive gap, which means the score of the "Priority Indicator" is high, the user has to make improvements to meet certain external requirements and logically, the order of the gap has to be considered to provide information on the severeness of environmental problems. By using the priority indicator, the general aim is to filter out and classify the actions. Then the related adaptive programs must be created to achieve the requirement, meanwhile to minimize the gap.

The "priority indicator" focuses on the final objective. Other additional criteria could be used to fix the detail of needs. Some examples presented in below table explain the function.

Type Name	Description	The further requirements
Reponses preferred	*Great gap = "Gravity" – "Achievement"*	The main criterion is the response speed
Organization preferred	*Great gap = "Feasibility" – "Implementability"*	The current organization or process has to be changed
Effect preferred	*Great gap = "Visibility" – "Communication"*	The promotion plan need to be involved
Leadership preferred	*Great gap = "Visibility" – " Gravity"*	Creation of needs, creation of the leadership
Promotion preferred	*Great gap = "Achievement" – "Communication"*	Need the depth promotion of victory

Tableau 41: some examples of decision criteria of ECA normalization method

This tool supports also the prioritization of the profit from actual achieved ECAs. A negative gap between external score and internal score means that the enterprise has met and exceeded the external requirement of the ECAs. The bigger is the negative gap, the more advance is the environmental profile. To achieve the target of being a leader in the industry, the ECAs selected by the order of negative gap, are focused on marketing education and promotion plan to amplify these advantages. These marketing plans attract the public on their greener performance, and will eventually increase the external requirement. Then, it could finally lead to the increase the global external score of the ECA, and then to the reduction of the gap. Furthermore, some ECAs can be selected as innovation tendencies. By calculating the indicators, the enterprise could further develop the technology and marketing influence for such ECAs. These actions will increase the internal scores and consequently create the negative gap. With the influence plan or other competition activities, such ECA's external scores will be increased, thus will finally re-reduce the gap.

In all the cases, this assessment method proposes a quantifiable system to select adapted environmental concerns action group. The gap between external score and internal score could be considered as a "Motor" with the "Reduction of the gap" as the general tendency of development. This evaluation method has to continuously monitor the situation and adjust the scores of indicators till the gap between the external and internal situation is small enough.

QFD-Based tools

This is an application of traditional QFD method in environmental domain which enables to systematically assess the relationship between the environmental needs and the technical correlations. Finally, the assessment result is to guide the user how to meet the needs and requirement [Utne I.B., 2009].Based on the traditional QFD approach, there are several propositions, listed in the following table. According to the analysis of [Puglieri F.N., 2011], there are a systematic summary to evaluate (by environmental and operational criteria) all different QFD-based environmental tools.

Name	Reference	Environment			Operation					
		Life cycle phases	Regulation	Environmental impacts	Easy to use	Cost	Time to use	Validated	Benefits visualization	Trade of analysis
3D-QFDE	*[Shih, L., 2005]*	3	1	2	2	3	2	1	3	1
Eco-QFD	*[Ernzer, M.]*	3	1	1	3	3	3	2	1	1
	[Kuo T.C., 2009]	2	1	1	1	2	2	3	3	1
	[Utne I.B., 2009]	1	1	2	3	3	2	1	3	2
Eco-VOC	*[Yim, H., 2003]*	3	1	1	3	3	2	1	3	1
Environmental QFD	*[Kato, S., 2003]*	3	2	1	2	1	2	3	3	1
EI2QFD	*[Ernzer M, 2003]*	3	1	2	2	2	1	1	3	1
IGQFD	*[Cagno, E., 2007]*	2	1	2	2	3	2	3	3	2
GQFD	*[Wong, K., 2000]*	2	2	1	2	3	3	1	1	2
Green QFD	*[Zhang Y., 1999]*	3	1	2	2	1	1	1	3	3
QFD	*[Hochman, S., 1993]*	1	1	1	3	3	2	1	1	2
	[Wolniak, R., 2008]	1	2	2	3	3	3	2	1	2
QFD Based on RSP	*[Sakao, T., 2003]*	1	1	1	3	3	2	3	3	1
QFD-DfE	*[Rahimi, M., 2002]*	3	1	1	3	3	3	1	3	3
QFD-LCA-TRIZ	*[Sakao, T. A, 2007]*	3	1	3	2	1	1	3	3	1
QFD-LCA	*[Sakao, T. A, 2005]*	3	1	3	2	1	1	1	3	1
QFDE	*[Masui K., 2001]*	3	1	2	3	3	2	3	3	1

Note: This table is to evaluate the QFD-based environmental prioritization tools by the answering level of certain criteria.

Score 3 → this tool totally considers this criterion
Score 2 → this tool partially considers this criterion
Score 3 → this tool doesn't considers this criterion

The description of evaluation criteria:

- *Life cycle phase: Environmental requirements are considered in whole product's life cycle*
- *Regulation: Environmental legislation and standards are considered as the product requirement*
- *Environmental impacts: The environmental impacts are considered as technical requirements (as quality characteristic) that allow to be correlated with the quality requirements from client*
- *Easy to use: The tool has its stages of implantation detailed and does not use complex mathematical language*
- *Cost: The tool requires the purchasing of software, hiring of experts and/or training*
- *Time: The tool has a higher number of steps that its traditional version*
- *Validated: The tool was applied to businesses*
- *Benefits of visualization: The tool presents the main results and benefits of its application*
- *Trade-off analysis: The tool identifies the relationship/conflict between environmental requirements and product quality/quality characteristics*

Tableau 42: Evaluation of QFD-based environmental prioritization tools (Source: [Puglieri F.N., 2011])

The following chapter presents the contents of GQFD to make the example of this type of tool.

GQFD uses the QFD method and the life cycle impact analysis to generate the final technical requirements. The GQFD-II extends the applicable domain which covers the LCA, LCC and the "Voice of Customers for quality". GQFD-III reduces the workload in GQFD-II by use of Eco-Indicator 99 methodology instead of full LCA, and integrates the Analytic Hierarchy Process (AHP) for selecting the best system concept [Utne I.B., 2009]. The GQFD includes three major phases:

- Phase I: Technical Requirement Identification. In this phase, the “Green house-GH” is established to generate the requirements derived from LCA. For GQFD-II, the “Quality house”, generate the requirement from “Voice of Customers”, and the “Cost house”, generate the requirement from LCC, should be also established to complete the systematic requirements list.

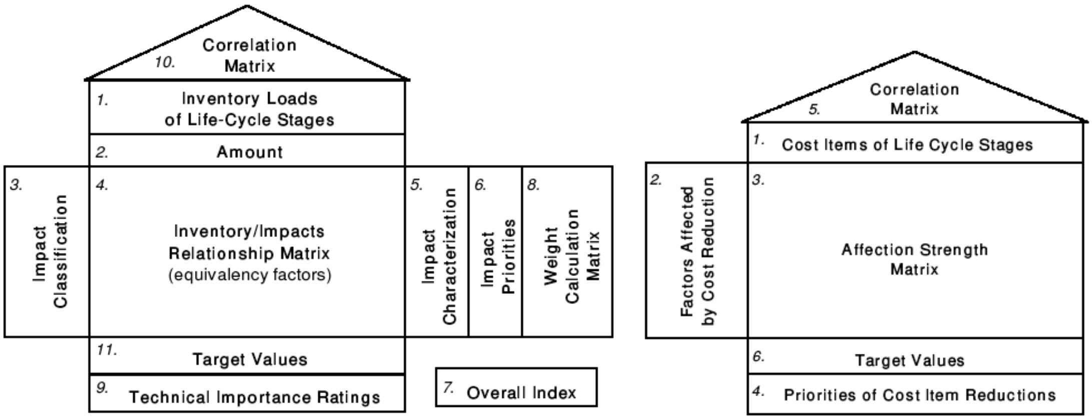


Figure 16: Green house and cost house of GQFD-II tool [Zhang Y., et al., 1999]

- Phase II: Product Concept Generation. A series of alternative product concepts are generated to satisfy the requirements from phase I. Through the Concept Comparison House (CCH), these concepts can be evaluated with respect to quality, environment and cost. The best product concept is then selected and the related product development activities are the reorganized [Zhang Y., et al., 1999].

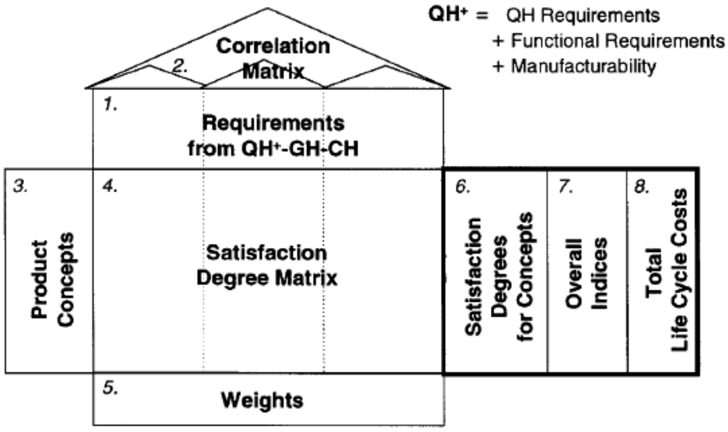


Figure 17: Concept Comparison House of GQFD-II tool [Zhang Y., et al., 1999]

- Phase III - Product/Process Design. In this phase, a set of planning should be established to ensure the design. These planning include the design deployment, process planning, production planning, maintenance planning, and retirement planning. Some matrices, similar with the traditional QFD could be used to generate them. [Zhang Y., et al., 1999].

Spider diagram comparison

Spider diagram is a graphical tool that displays multivariate data in the form of a two-dimensional chart of three or more quantitative variables represented on axes starting from the same point.

For environmental assessment, the spider diagram is a qualitative or semi-quantitative tool which supports a graphical presentation of the level of environmental impacts. This tool is usable to ensure the straight promotion and the easier understanding. Typically, this tool is used to directly compare the difference among several products. This type of direct graphical result supports a rough and quick estimation for choosing the best design alternative [Tischner et al., 2000]. If all necessary information is sufficient, the time for preparing this graph is very small.

To complete a spider diagram, the indicators and the related criteria to evaluate the level of indicators should be pre-defined. Practically, these indicators need to be agreed with previous evaluation tools, such as the check list, the LCA-Matrix, etc. Today, the LCA software has involved this type of tool. So the additional individual action corresponds with the all other no-software-based tool.

Environmental targets directly supported by Spider diagram comparison

- **Diagram comparison of environmental performance between actual product with reference product**
- **Diagram validation the environmental improvement comparing with reference**

Actions chain of targets supported by spider diagram comparison

Action chain of the target: Diagram comparison of environmental performance between actual product with reference product

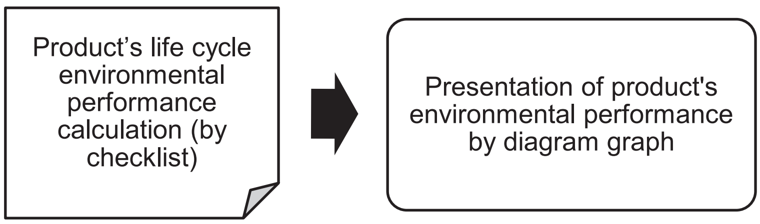


Figure 18: Action chain of target - Diagram comparison of environmental performance between actual products with reference product

Action 1: Presentation of product's environmental performance by diagram graph

According to the reference product, translate the product’s environmental performances, which are presented by certain impacts/ indicators, into the points on spider diagram.

Inputs/Outputs necessary for this action

Input	Output
Product’s environmental performances (by checklist answers – impacts/indicators)	Product’s environmental performance spider diagram
Compared reference (product/service)	

Tableau 43: I/O list of action - Presentation of product's environmental performance by diagram graph

The competence necessary

- ✓ The knowledge of documentation

Action chain of the target: Diagram validation the environmental improvement comparing with reference

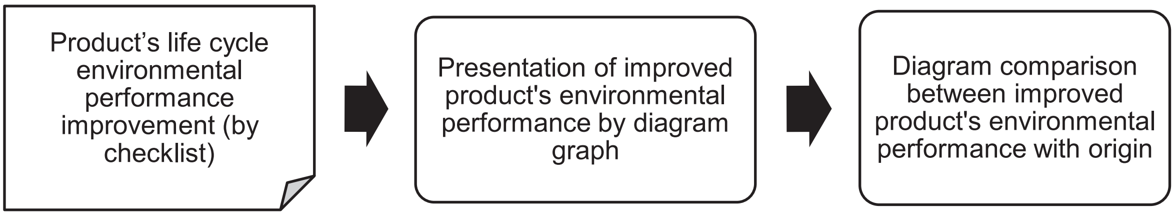


Figure 19: Action chain of target - Diagram comparison of different product's environmental performances

Action 1: Presentation of improved product's environmental performance by diagram graph

Translate the improved product's environmental performances, which are presented by certain impacts/ indicators, into the points on spider diagram

Inputs/Outputs necessary for this action

Input	Output
Improved product's environmental performances (by checklist answers – impacts/indicators)	Improved product's environmental performance spider diagram
Compared reference (product/service)	

Tableau 44: I/O list of action - Presentation of improved product's environmental performance by diagram graph

The competence necessary

- ✓ The knowledge of documentation

Action 2: Diagram comparison between improved product's environmental performances with origin

Compare the improved performances and the original performances in a same spider diagram

Inputs/Outputs necessary for this action

Input	Output
Product's environmental performance spider diagram	Diagram comparison between improved product's environmental performances with origin
Improved product's environmental performance spider diagram	

Tableau 45: I/O list of action - Diagram comparison between improved product's environmental performances with origin

The competence necessary

- ✓ The knowledge of documentation

Spider diagram references

The spider diagram is an efficient tool to display the environmental performance by a set of predefined indicators. Some existing tools are presented as below:

Eco compass

LCA data is usually too complex and detailed to make sense to most business decision makers. Consequently, there is a need for a means of weighting the inputs and outputs to clarify important issues and make comparisons between options.

The eco-compass technique, developed at Dow Europe, is a comparative tool to evaluate one existing product with another, or to compare a current product with new development options [Yan P.T., 2002]. “Eco compass” proposes 6 dimensions of indicators to evaluation the product’s environmental performances: The “Mass intensity”, the “Energy intensity”, the “Revalorization”, the “Resources conservation”, the “Health and environmental risks” and the “service extension”:

Mass Intensity (the quantity of material used per functional unit): is the amount of material used during the entire life cycle phases of product [Jones E., 2000].

Energy Intensity (quantity energy used per functional unit): is the energy consumption at all stages of the product’s lifetime [Jones E., 2000].

Service extension (increasing quantity of functional units in the product): considers ways of delivering more service to customers. This can be achieved by increasing product: durability, reparability, upgradeability, multi-functionality or shared use of the product.

Health and Environmental Risk (quantity of hazardous substances emitted to air soil and water): Toxicologists try first to identify the ways in which a product or process creates health and environmental risks. Secondly, to consider the importance of the risk identified [Jones E., 2000].

Resource Conservation (quantity of scarce or depleting resources used): Focuses on the nature and re-newability of the energy and materials needed for a product or process. It considers the overall impact of specific resource needs [Jones E., 2000].

Revalorization (quantity of waste not Eco-efficiently recycled): includes several different approaches to waste. The main aim is to close the loop on materials and products by recycling (converting wastes back into raw materials) re-use and remanufacturing (refurbishment of complete products or components) [Jones E., 2000].

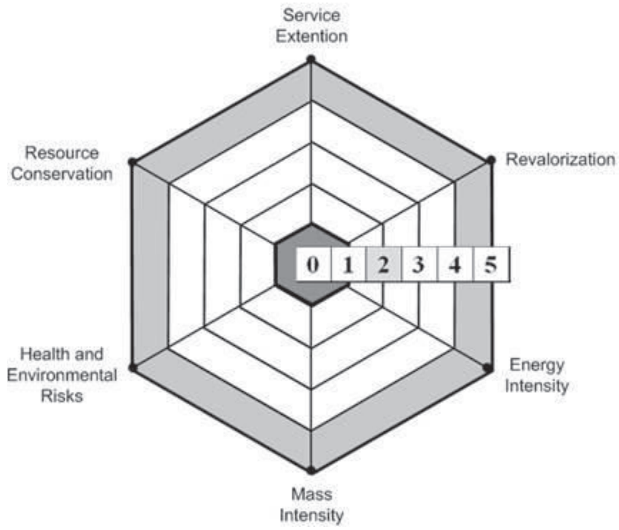


Figure 20: “Eco Compass” Structure

Before using this tool, the necessary environmental related data should be collected to ensure the creditable comparison. But, this tool is considered useless for single product’s assessment [Tischner et al., 2000]. The main purpose of “Eco compass” is to be used as a qualitative scoring and display tool to direct compare the environmental performances between different products or design alternatives.

A score making system, from 0 to 5, is used to rate the performance level of each dimension. Initially, one of the products to be compared is identified as a reference which is always scored at level “2” for each of six dimensions. The alternative product is then given a relative score depending on the percentage of increase or decrease of each performance, higher rating means better performance.

Spider web diagram by E-concept

This spider web diagram tool, developed by "E-concept", is an "eight-axis" qualitative spider diagram [WONG, Y.L., 2009], [Tischner et al., 2000]. There is a database of the environmental axes ensures the flexible corporate set of display criteria. Some typical criteria proposed as below:

Product aesthetics	Longevity
Resource efficiency (such as material efficiency and energy efficiency)	Fulfillment of needs
Satisfaction of customer needs	Sustainable use of renewable
Avoidance of hazardous substances	Waste and emissions
Recyclability	Cost efficiency

Tableau 46: The typical criteria proposed by spider web diagram

For each criterion, there are seven hierarchical levels, from 0 to 8, to judge the environmental performances, higher rate means better performance.

Product-oriented streamline LCA

The LCA approach is a systemic evaluation tool to holistic analyze the product's environmental profiles, so this complex requirement needs a vast number of detailed data to support it. Due to the level of detail of data required, a full LCA is most applied in the later stages of product development, when product's specifications are established [Bocken N.M.P., 2012].

In order to involve the LCA approach at the earlier design phase and reduce the implementation difficulty (The number of data collected, the implementation time, the combination between the different environmental impacts, etc.), some streamlined LCA approaches were developed. The final goal of this approach is to reduce the difficulty of the LCA implementation by restricting the assessment to one specific indicator, such as the material inputs, energy consumption or CO_2 emissions, etc.

The streamlined LCA is a straight and simple tool to answer some specific needs. The main weakness of this approach is the lack of an analysis and highlight system to avoid the environmental impacts transfer.

Environmental targets directly supported by product-oriented streamlined LCA

- **Product's streamlined life cycle calculation**

  The main purpose of this target is to obtain the quantitative results of product's life cycle streamlined environmental impacts.

- **Product's life cycle environmental performance evaluation**

  Noticed in "Product-oriented quantitative LCA" chapter

- **Product's life cycle environmental performance improvement**

  Noticed in "Product-oriented quantitative LCA" chapter

Actions chain of targets supported by product-oriented streamlined LCA

Because the streamlined LCA approach has the similar implementing process with classical LCA, the LCA software, the matrix LCA approach and other semi-quantitative/Qualitative LCA tools could be also used to support this streamlined need.

Action chain of the target: Product's streamlined life cycle calculation

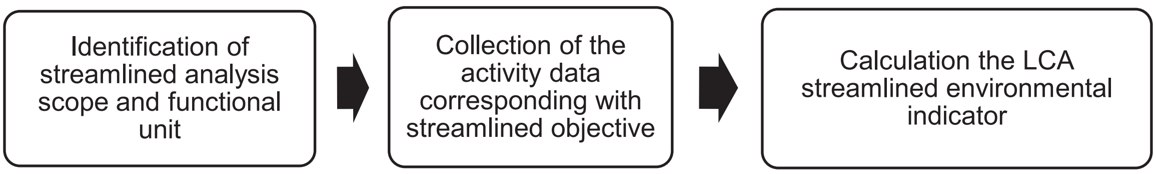


Figure 21: Action chain of target - Product's streamlined life cycle environmental performance calculation

Action 1: Identification of streamlined analysis scope and functional unit

At first, this action defines which product or product family (with the functional unit definition) will be covered by this analysis. According to this scope definition, an analyzed system boundary and the determine priorities have to be identified. The system boundary defines the related process, activities and the materials map that contribute to each stage of the chosen product's life cycle phase. The determine priorities focuses on the main impact sources and eliminate negligible others [PAS 2050, 2008]

Inputs/Outputs necessary for this action

Input	Output
Product list	Products list of analysis scope
	Definition of functional unit
	The process and activities map
	The determine priorities

Tableau 47: I/O list of action - Identification of streamlined analysis scope and functional unit

The competence necessary

- ✓ The knowledge of identification of product family (If need)
- ✓ The knowledge of the functional unit and how to identify the functional unit
- ✓ The knowledge of environmental concerned elements determination
- ✓ The knowledge of LCA

Action 2: Collection of the activity data corresponding with streamlined objective

According to the previous definitions, collect the environmental concerned elements to describe the streamlined impact. While the collection, the right data unit and the related factors might to be identified and noted. If possible, the primary data on actual meter is preferred.

Inputs/Outputs necessary for this action

Input	Output
Products list of analysis scope	Products life cycle environmental concerned elements list
Definition of functional unit	Elements list of product's constitution
The process and activities map	Elements list of transport/logistics
The determine priorities	Elements list of Installation / utilization / Maintenance
	Elements list of product's end of life

Tableau 48: Collection of the activity data corresponding with streamlined objective

The competence necessary

- ✓ The channel and the knowledge to collect the data
- ✓ The knowledge of data treatment

Action 3: Calculation the LCA streamlined environmental indicator

According to product's life cycle environmental concerned elements list, this action requires to calculate the streamlined environmental indicator results

Inputs/Outputs necessary for this action

Input	Output
Products life cycle environmental concerned elements list	Product's streamlined life cycle environmental performances *(presented by indicators per life cycle phase)*

Tableau 49: I/O list of action - Calculation the LCA streamlined environmental indicator

The competence necessary

- ✓ The knowledge of environmental impacts evaluation

Product-oriented streamlined LCA references

Product carbon footprint

A product carbon footprint measures the GHG emissions over the whole life of a product (goods or services), from the extraction of raw materials and manufacturing right through to its use and final reuse, recycling or disposal. At each stage the analysis should include GHG emissions resulting from any material inputs to, or outputs from, the process. Commonly, these include energy use, transportation fuel and direct gas emissions such as refrigerant losses from air conditioning units and waste [PAS 2050, 2008].

The implementation process has been set up by British Standardization Institution PAS 2050. This process is similar with the standard LCA. Some supportable information is available in the implementation guide, such as the GHG factor of local fuel source and the GHG CO_2 equivalent list.

Step 1	Step 2	Step 3	Step 4	Step 5
Build a process map	Check boundaries and determine priorities	Collect data	Calculate the footprint	Verify your footprint
List all of the materials, activities and processes that contribute to each stage of the chosen product's life cycle.	Some emissions can be excluded, e.g. consumer travel to retail outlets. Calculating a high-level footprint first will help focus data collection on the main GHG emission sources and eliminate others.	Collect activity data (e.g. liters of fuel consumed per product unit) and select appropriate emissions factors (e.g. kgCO2 per liter of fuel). Where possible, use primary data based on actual meter readings or records rather than estimates.	Calculate the GHG emissions (kgCO2e per product unit) from each source by multiplying the activity data by the emissions factors. Assessing the product footprint	You can verify your footprint in three ways: • self-verification • verification by another party, such as another company • accredited independent third-party verification.

Tableau 50: The working process of calculate the product carbon footprint (Source: [Carbon Trust, 2012])

MIPS

Material input per service unit (MIPS) is a quantitative life cycle assessment tool to analyze the environmental impacts caused by the material inputs [Ritthoff, Rohn, & Liedtke, 2002]. The basic concept of this tool is that fewer materials used leads to less environmental impacts. MIPS provide a tool and related data to make a simplified LCA comparison between two products or services by directly comparing the material and energy inputs of each "mass unit" or "service unit" during the whole life cycle. The "service unit" has the similar definition of "Functional unit" from standard LCA.

Some necessary definition:

MI: Material input

MIT: material intensity presents the material inputs (MI) in relation to weight unit.

The Material inputs are classified into five categories: [Ritthoff, Rohn, & Liedtke, 2002]

- Abiotic raw materials – mineral raw materials, fossil energy and soil
- Biotic raw materials – biomass from cultivation and uncultivation areas
- Earth movements - mechanical earth movement or erosion
- Water – Surface water, ground water and deep ground water
- Air – Combustion, Chemical transformation and physical transformation (aggregate state)

Each real material used should be projected to these five categories. For example, 1 MWH electric power (public supply FRG) presented 4.7 tons abiotic material 83.1 tons water and 0.6 tons air [Ritthoff, Rohn, & Liedtke, 2002]. These values are named as "MI factors". The "Wuppertal institute", the developer of MIPS tool, provides some references for normal inputs.

The process of MIPS includes seven steps:

1. Terms, objective - definition of “service unit”.
2. Representation of process chain – identify a diagram to illustrate the detailed of relationship between all individual processing steps.
3. Compiling of data – Collect the real material and energy inputs data of each processing step, as complete as possible.
4. MI “from cradle to product” – calculate the MI value (according to MI factors) of up-stream life cycle according to collected data
5. MI “from cradle to grave” – calculate the MI value (according to MI factors) of down-stream life cycle according to the resource consumption in using and end of life phase.
6. From MI to MIPS – Calculate the MIPS by dividing the entire MI data (Step 4 and 5) by the number of “service unit”
7. Interpretation of results

The practical use of this MIPS tool very lies on the quality and completeness of collected data. The knowledge of product manufacturing process and the data collection channel are very important, especially, without the pre-defined inventory module to provide the information. So a preparatory process is necessary to company. This process could fix the analyzing frontier and collect the related data. To complete the results, the production function, purchasing department (collect the supplier’s information) and environmental experts might be involved.

This approach measures whole life cycle resource inputs required to produce a product or a service. But this tool doesn’t directly account some significant negative outputs, such as the pollution, waste and emissions, etc. Some negative impacts of outputs don’t depend on the using volume of inputs, such as the compatibility between different plastics for dismantling. So this tool is not very holistic.

CED

“Cumulative energy demand analysis”, named also as “CERA” was developed by IFIAS (International federation of institutes for advanced studies). The CED presents the entire energy demand, valued as primary energy during the whole life cycle phases of a product [Frischknecht R., 2006]. Similar with MIPS, the CED analyzes the environmental impacts due to the energy consumption, and CED believes that this result could approximate the results of standard LCA, because of the energy presents the significant environmental impacts. [Frischknecht R., 2006] compared the environmental impacts value (presented by multi-indicators: global warming, stratospheric ozone depletion, acidification, Eutrophication, photochemical ozone formation, land use, resource depletion and human toxicity) from CED tool and standard LCA. The study results show that the CED analysis correlated well with most indicators, without waste treatment. So this is a screening impact indicator to provide an overview of global environmental performance.

The Cumulative energy demand (CED) collect all direct and indirect energy inputs throughout the whole life cycle of product, including the energy consumed during the exploration, manufacturing and disposal phase. Direct energy inputs refer to all primary energy input required for product manufacture, use and end-of-life. Indirect energy inputs refer the energy inputs that are used for other purposes than manufacturing, such as infrastructure and equipment.

As a standard LCA tool, the first step of CED is to identify the function units and analysis frontier. According to these definitions, the second step is to collect all related data, the energy consumption in each life cycle phase. The total cumulative energy demand is considered as the summary of for sub-groups: CED of production, CED of utilization, CED of disposal and CED of other related energy inputs. The CED of production does not only calculate the energy consumption at product level, it also requires touching the sub-component and material production [WONG Y.L., 2009].

$$CED_{Total} = CED_{Production} + CED_{Utilization} + CED_{Disposal} + CED_{Others}$$

Finally, the CED value of product could reflect its environmental performance, smaller number presents less impacts. This result could be used also to compare between multi-products.

Additional, the “Linear regression” was performed to relate the environmental impact scores with cumulative fossil energy demands. The data in all sub-groups were log-transformed in order to account for their distributions [Frischknecht R., 2006].

According to the results of environmental impacts, a dashboard of environmental performance of product could be released.

Some information of the coefficients of each environmental indicator contribution and the calculation of CED has been proposed by different authors [Frischknecht R., 2006], [WONG, Y.L. 2009].As other LCA tools, the CED requires a preparatory process to collect the related information. This process might include the R&D department, the production, the purchasing department (collect the supplier’s data) and environmental expert to complete the data.

Product-oriented Guideline

Guideline is a widely used tool to guide the users to adapt the product to environmental demands and address the environmental improvable targets. The guideline is different with checklist. The guideline provides the environmental expertise to guide the improvable tendency and solution to resolve the environmental problems which have been previously identified by the checklist. And also, the guideline might provide the necessary information to prepare the checklist, such as a checklist requires the free of the “black and gray list” material which is furnished by the guideline “Black, white and gray material list”, etc.

Typically, the guideline is used at the beginning of the working process, to support the identification of product’s environmental checklist and the improvement specification. According to the different applicable area, the guideline tends to focus on multi-criteria of all types of product during the whole life cycle phases, or just focus on the specific product’s one life cycle phase.

Environmental targets directly supported by product-oriented guideline

- **Environmental guideline exploration and identification**

Actions chain of targets supported by product-oriented guideline

Action chain of the target: Environmental guideline exploration and identification

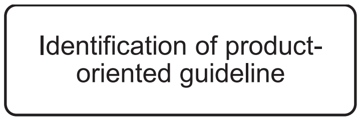


Figure 22: Action chain of target - Identification of the environmental guideline

Action 1: Identification of the environmental guidelines

According to the targeted product category, the real objectives of environmental improvement, the user explores the existing guideline or identifies / customizes the guidelines to support the needs of eco design.

Inputs/Outputs necessary for this action

Input	Output
Product category	Product-oriented environmental guideline
Environmental targets	

Tableau 51: I/O list of action - Identification of the environmental guidelines

The competence necessary

- ✓ The knowledge of environmental concerned elements determination
- ✓ The knowledge of environmental improvement
- ✓ The knowledge of LCA

Product-oriented guideline reference

Name	Proposal	Description	Reference
Black, White and Gray material list	Material	Provides the material environmental profiles and using recommendation	See below
LiDS wheel	Life cycle – Multi criteria	Life cycle environmental improvement recommendation	See below
Ten Golden rules	Life cycle – Multi criteria	Life cycle environmental improvement recommendation	See below

Alternative fibers and fabrics environmental database	End of life	A database including end of life Property and opportunity of alternative fibers	CRR Corporate wear Project, 2008-2009
Eco D'EEE	End of life	Guideline of disassembly and recycling improvement	[CODDE, 2008]
Thermoplastic material computability for recycling	End of life – material recycling	Compatibility table for recycling (between thermoplastic materials)	[VDI 2243 2002]
Design for disassembly guideline	End of life	Guideline to guide the disassembly and recycling improvement	[Chiodo J., 2005]
Design for product lifetime	End of life	Multi guidelines group for disassembly, remanufacturing, update, recycling and repair	Autodesk website[1]
Biodegradable composites based on lignocellulosic fibers	End of life	The biodegradable performances of fibers	[Satyanarayana K.G.,2009]
Hazardous material in textile and clothing product	Material	The hazardous material for healthy	[WWF, 2011]
Sustainable flame retardant	Material	Review of the using of flame retardant and the identification of sustainable FR	[Horrocks A.R.,2005]
Nano-structured materials	Material	Review of nano-structured materials utilization	[Dastjerdi, 2010]
Material selection for sustainability	Material	General material selection guideline	[Ljungberg L.Y., 2007]
Notes: 1. http://sustainabilityworkshop.autodesk.com/media/engineers/resource/DfLifetime_QuickReferenceGuide_AdskSustainabilityWorkshop_large.pdf			

Tableau 52: The summary of product-oriented guidelines

Black, white and gray material list

"Black, White and Grey lists for substances/materials" is a common tools to support the material selective decision. This tool provides the company to build three short-lists to organize the corporate material/substance database: the White list, Black list and Grey list.

White List: also referred to as "clean list" or "recommendation list", identify the materials/substances that are low environmental risks or that have been approved for import. The key idea behind this whit list is that the company and design project prefer and totally authorize to use [Burgiel S., 2006], [Luttropp C., 2006].

Black list: also referred to as "dirty list" or "Forbidden list" identify those substances/materials whose potential effects on the environment or human health [Burgiel S., 2006]. The second reason comes from the actual legal or corporate restricts. The key idea behind this whit list is those material in this list is absolute prohibited to be use in product and process.

Gray list: also referred to as "low-priority list" identify those substances/materials that might be used, without the recommendation, if there is a good raison or there is not an available solution to remove them [Luttropp C., 2006]. The material/substance in this list might present the higher environmental impacts that could not be determined conclusively and frequently or those have not yet been prohibited, but will be, by the law or corporate restricts. Additional, some supplementary required action and information might be also registered into the database. For example, if a material should be used, an official declaration should be done to explain the reason to grand public.

These lists support the product material selection by product designer. They could also support the supplier management to validate the material/substance inputs.

Typically, the three types of lists are used individually and sometimes in combination. The individual utilization is to verify if certain material/substance is authorized or temporary authorized and explore the additional actions. The combinative utilization lies on the data bridges between three lists. This data bridge provides the replacement rules and suggestions for black and grey list.

The success of this list system lies on its completeness, adaptability and flexibility of related risk assessment. There are two types of criteria of risk assessment, the absolute criteria and relative criteria. The absolute criteria analyze the material/substance characteristics and judge it. The relative criteria analyze the relationship between different materials and define certain substances are forbidden, if someone has been used. A typical example of relative criterion is the compatibility analysis for plastics recycling performance. (Plastic A is compatible with B, incompatible with C, for example).

To ensure the efficacy of this list system, it requires a preparatory process seeking to obtain further information, particularly with regard to the efficiency and the process for movement from one list to another. This preparatory process need to involve the material and environmental experts. Some other product-oriented functions (Designer, Purchasing and product marketing) might be also involved to optimize the perimeter and priority of analysis.

LiDS Wheel

Life Cycle Design Strategy Wheel – LiDS wheel, developed by Carolien Van Hemel and Han Brezet in 1997, is acted as an eco design creativity technique to select improvement options for products [Yan P.T., 2002].

LiDS wheel proposes seven potential eco design strategies which cover the entire product's life cycle phases at the product's component level, product's structure level and the product/system level. The list of strategies shows as below:

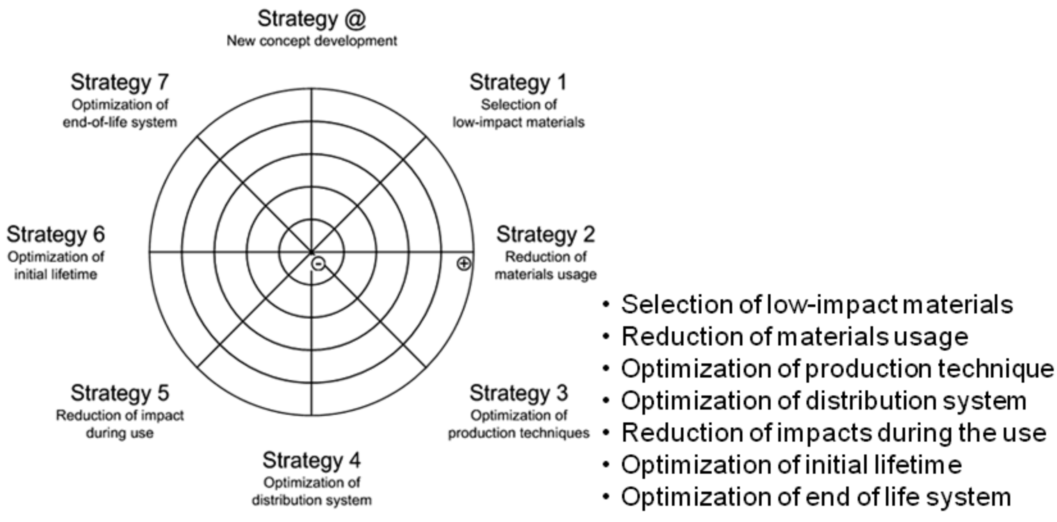


Figure 23: LiDS wheel structure

Initially, the tool's user has to analyze the actual product's environmental profiles during the entire life cycle phases and rate them from 0 to 5. To support this action, [Brezet H., 1997] developed a checklist with multi-questions (listed in the follow table – left column) to identify the degree of impact level. The questions are regrouped by the life cycle phase and focus on the significant problems. For environmental impact category, in right column of following table, there are some related potential strategies might resolve them. The multi-disciplines collaborate together to identify the final strategies group and the related working targets.

Eco design Checklist	Eco design Strategies
Need analysis	
How does the product actually fulfill social needs? - What are the products main and auxiliary functions? - Does the product fulfill these functions effectively and efficiently? - What user needs does the product currently meet? - Can the product functions be expanded or improved to fulfill users' - Will this need change over a period of time? - Can we anticipate this through (radical) product innovation?	Eco design strategy @ New concept development - Dematerialization - Shared use of the product - Integration of functions - Functional optimization of product (components)
Life cycle stage 1: Production and supply of materials and components	
What problems can arise in the production and supply of materials and components? - How much, and what types of plastics and rubber are used? - How much, and what types of additives are used? - How much, and what types of metals are used? - How much, and what other types of materials (glass, ceramics etc) are used? - How much, and which type of surface treatments is used? - What is the environmental profile of the components? - How much energy is required to transport the components and materials?	Eco design strategy 1 Selection of low-impact materials - Clean material - Renewable materials - Low energy content materials - Recycled materials - Recyclable materials Eco design strategy 2 Reduction of material usage - Reduction in weight - Reduction in (transport) volume
Life cycle stage 2: In-house production	
What problems can arise in the production process in your own company? - How many, and what types of production processes are used (including connections, surface treatments, printing and labeling)? - How much, and what types of auxiliary materials are needed? - How high is the energy consumption? - How much waste is generated? - How many products don't meet the required quality norms?	Eco design strategy 3 Optimization of production techniques - Alternative production techniques - Fewer production steps - Low/Clean energy consumption - Less production waste - Few/Clean production consumables
Life cycle stage 3: Distribution	
What problems arise in the distribution of the product to the customer? - What kind of transport packaging, bulk packaging and retail packaging are used (volumes, weights, materials, reusability)? - Which means of transport are used? - Is transport efficiently organized?	Eco design strategy 2 Reduction of material usage - Reduction in weight - Reduction in (transport) volume Eco design strategy 4 Optimization of the distribution system - Less/Clean/Reusable packaging - Energy-efficient transport mode

	- Energy-efficient logistics
Life cycle stage 4: Utilization	
What problems arise when using, operating, servicing and repairing the product? - How much, and what type of energy is required, direct or indirect? - How much, and what type of consumables are needed? - What is the technical lifetime? - How much maintenance and repairs are needed? - What and how much auxiliary materials and energy are required for operating, servicing and repair? - Can the product be disassembled by a layman? - Are those parts often requiring replacement detachable? - What is the aesthetic lifetime of the product?	Eco design strategy 5 <u>Reduction of impact in the user stage</u> - Low energy consumption - Clean energy source - Few consumables needed - Clean consumables - No wastage of energy or consumables Eco design strategy 6 <u>Optimization of initial lifetime</u> - Reliability and durability - Easy maintenance and repair - Modular product structure - Classic design - Strong product-user relation
Life cycle stage 5: Recovery and disposal	
What problems can arise in the recovery and disposal of the product? - How is the product currently disposed of? - Are components or materials being reused? - What components could be reused? - Can the components be disassembled without damage? - What materials are recyclable? - Are the materials identifiable? - Can they be detached quickly? - Are any incompatible inks, surface treatments or stickers used? - Are any hazardous components easily detachable? - Do problems occur while incinerating non-reusable product parts?	Eco design strategy 7 Optimization of the end-of-life system - Reuse of product (components) - Remanufacturing/Refurbishing - Recycling of materials - Safe incineration

Tableau 53: The checklist and propositions of eco design strategies (Source: [Brezet H., 1997])

Ten Golden Rules

Developed by [Luttrop C., 2006], The ten Golden Rules is a generic guideline to guide the integration of the environmental consideration into product development process. The enterprises can also develop more concrete and specific guidelines by customizing and transforming the ten golden rules in relation to their own specific product development context. The typical “Ten golden rules” is summarized as follow:

Rule 1	Product constitution / Production	Do not use toxic substances and utilize closed loops for necessary but toxic ones
Rule 2		Minimize energy and resource consumption in the production phase and transport through improved housekeeping
Rule 3		Use structural features and high quality materials to minimize weight .in products .if such choices do not interfere with necessary flexibility, impact strength or other functional priorities
Rule 4	Usage	Minimize energy and resource consumption in the usage phase, especially for products with the most significant aspects in the usage phase.

Rule 5		Promote repair and upgrading, especially for system-dependent products. (e.g. cell phones, computers and CD players)
Rule 6		Promote long life, especially for products with significant environmental aspects outside of the usage phase
Rule 7		Invest in better materials, surface treatments or structural arrangements to protect products from dirt, corrosion and wear, thereby ensuring reduced maintenance and longer product life
Rule 8	Usage/Maintenance	Prearrange upgrading, repair and recycling through access ability, labelling, modules, breaking points and manuals
Rule 9		Promote upgrading, repair and recycling by using few, simple, recycled, not blended materials and no alloys
Rule 10		Use as few joining elements as possible and use screws, adhesives, welding, snap fits, geometric locking, etc. according to the life cycle scenario

Tableau 54: The generic list of “Ten Golden Rules”

Design for recoverability

Recently, the recoverability becomes an emphasis due to the fact that the increase of used product quantity and the exhausting mineral resources. It has been recognized that disassembly of used products and the recycling of materials are necessary in order to make recycling economically viable [Kuo T.C., 2001]. [Woolridge A.C., 2006] shows that the reuse of 1 tone of polyester garments only uses 1.8% of the energy required for manufacture of these goods from virgin materials and the reuse of 1 tons of cotton clothing only uses 2.6% of the energy required to manufacture those from virgin materials. But normally, the designer only considered the assembly operations to make easy the production process and improve the quality [Boothroyd G., 1994]. In order to answer the external requirements for recoverable performance of products, the designers need to consider in terms of disassembly and parts recycling as well [Kuo T.C., 2001].

Design for recoverability is one of important tools in “DfX” series. The “recoverability” presents at the product’s disposal phase, the ability to recover back the product’s constituent into the production process. This series of tools, “Design for recoverability”, supports the user to improve the product’s recoverability at the end of life phase. According to the different recovering scenarios [Rose C.M., 2000], the “Design for recoverability” could be further divided into several sub-categories:

- Design for reuse
- Design for remanufacturing
- Design for disassembly
- Design for material recycling

Design for disassembly

Disassembly is defined by [Gungor A., 1999] and [Brennan L., 1994] as “a systematic method for separating a product into its constituent parts, components and subassemblies”. The disassembly could not be directly considered only as the reverse of assembly process, because of the complexity of disassembly operation, the different targets and the treatment of dangerous components [Santochi M., 2002]. Before the disassembly activities, a “disassembly plan” or named as the “disassembly depth” have to be identified. This plan needs to define the perimeter of the disassembled parts and the related operations. At first, the selection of the disassembled parts must be done according to the technical, environmental and economic constraints. [Smith S.S., 2011], [Westkamper E., 2000] and several authors summarized these constraints. The technical constraints focus on the location of the components (Where, What, How many and When), their accessibility (of components and fasteners) and the related disassembly tools. The economic impacts lie on the transportation cost, labor cost (step number of operation and reorientation, Duration, tools needed), the second material/component market, etc [Kuo T.C., 2000]. The environmental constraints focus on the hazardous material and the high risk operational activities. The requirement from legislation is a strong constraint to be followed. This perimeter might cover the whole product (all components should be disassembled and recycled), or certain prioritized parts (named as the single objective selective disassembly and multi-objectives selective disassembly). For each selected part, two generic scenarios are available: the non-destructive (for basic parts, loose parts or joining elements, etc.) and the destructive disassembly components [Santochi M., 2002]. Finally, according to the actual technical methods, a sequence of disassembly needs to be released to guide the step of disassembly, step by step.

The design for disassembly is to re-design the product’s structure and fixing mechanisms to optimize the dismountable performance which plays a significant role for recycling improvement. At the view of design, the disassembled components must be firstly identified. According to these targets, the designer evaluates if the actual disassembly process could answer all needs and if there are some improvable points could be done to optimize the sequences. Some necessary tools support the evaluation from different points of view: the accessibility, the cost, the time and the safety, etc. Depending on these evaluations, an improvement specification must be done to guide the further researches.

And also, the design could release a “disassembly instruction” to end of life treatment center to guide the real operation.

Design for material recycling

The “Design for material recycling” tool is proposed to guide the designer to improve the product’s recyclability performance at the end of life phase. Typically, the “Recyclability rate” is considered as a principal indicator which should be focuses on and improved. Through analyzing the existing tools, the “Design for material recycling” requires the some issues from “design for disassembly”, because normally, the recyclability rate after dismantling is higher than after shredding process. In order to define the improvement targets, identifying which components should be improved; the “recyclability potential” might be analyzed. This potential is focusing on the environmental benefits (such as the increasing of the recyclability rate, the environmental impacts reducing, etc.) and the economic benefits (the cost for recycling compared with the original material’s price, etc.) [Muthu S.S., 2012].

The end of life phase is one of the entire life cycle phases of product. The identification of the treatment scenarios and the related environmental achievements contribute the life cycle improvement.

Design for remanufacturing

Remanufacturing is “a process of returning a used product to like-new condition with a warranty to match” [Hatcher G.D., 2011]. More concretely, [Sundin E., 2005] defined the “remanufacturing” is as ‘‘a process of rebuilding a product, during which the product is cleaned, inspected and disassembled; defective components are replaced; and the product is reassembled, tested and inspected again to ensure it meets or exceeds newly manufactured product standards”. The remanufacturing process includes the sorting, inspection, disassembly, cleaning, reprocessing (Repairing, etc.) and reassembly. The remanufactured parts combine with the other original parts or no-remanufacturable parts to build a new product.

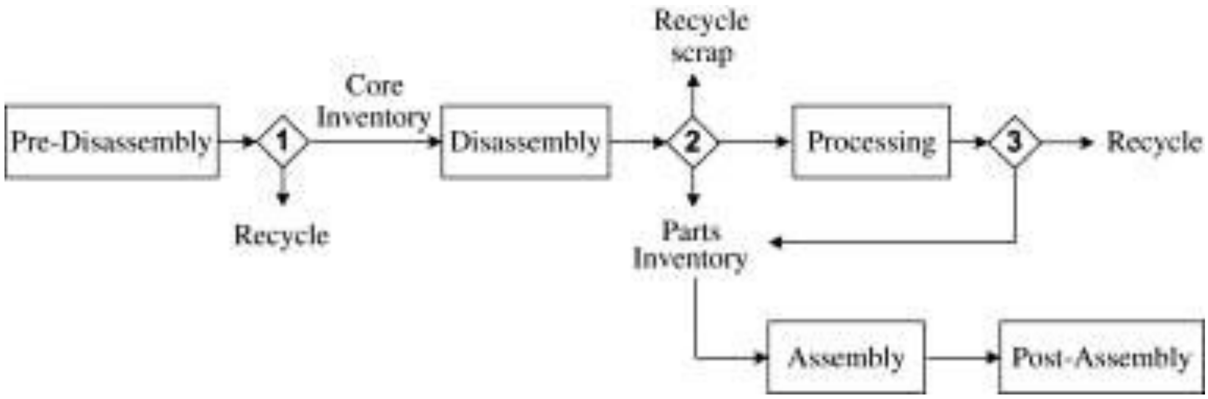


Figure 24: The process of remanufacturing (Source: [Sundin E., 2004])

The remanufacturing can benefit the environment because of the less material and energy consumption comparing with the new manufacturing process and the end of life treatment process of old one [Gutowski T., 2011], [Lindahl M., 2006]. Simultaneously, the saving of material / energy and the extending of product lifetime (subsequently sold for remanufactured components) could be translated to costing saving [Heese H., 2005].

The concept of “design for remanufacturing” as a design activity has arisen from the recognition that many of the technical barriers to remanufacturing can be related back to how the product was designed [Ijomah W., 2007[a,b]]. Remanufacturing steps, such as the disassembly, cleaning and reassembly cannot be efficiency if the product (previous model and the new product concept) has not been designed. And also, to recover the remanufactured parts in the new product, these recovering material flows should be involved into the supply chain management as a new component purchasing. If the remanufacturing process is charged by the product’s providers, the stocking management needs to be considered. So a "design for remanufacturing" is a combination process and concept to consider the product strategy, supply chain management, and the detail engineering of the product for facilitating any steps involved in remanufacturing [Nasr N., 2006], [Charter M., 2008].

Similar as the "design for recycling" and "design for disassembly", the "design for remanufacturing" is not an independent tool. In fact, a number of other tools factors could be considered simultaneously, such as the accessibility of each separation, the structure design, the geometry of fastening and joining methods, etc. Some operational factors, like the operational time, risks and the facility, is also important.

Environmental targets directly supported by design for recoverability

- **Recyclability rate calculation**

  According to different end of life treatment scenarios of product's components, this target is to calculate the potential product's recyclability rate in the design phase. This calculation could be based on the primary data (the information comes from the end of life recycler) or the secondary data (the regional/national/international average data).

- **Design for recyclability**

  This target requires the alternative design activities to improve the material recycling performance. The actual recyclability rate, the environmental benefits and the economic benefits have to be considered to make the final decision.

- **Design for disassembly**

  This target requires the alternative design activities to improve the product disassembly performance. The operational sequences, the product design, the operational performance (efficiency and risks) and the economic benefits have to be considered to make the final decision.

- **Design for remanufacturing**

  This target requires the alternative design activities to improve the product's remanufacturable performance. The operational sequences, the product design, the extending of lifetime, the operational performance (efficiency and risks) and the economic benefits have to be considered to make the final decision. Beside of these above technical points, the supply chain management, logistic management and stock management have to be considered also to ensure the whole integration into the normal manufacturing process.

Actions chain of targets supported by design for recoverability

Action chain of the target: Recyclability rate calculation

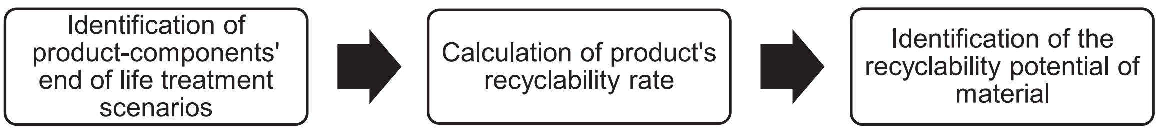


Figure 25: Action chain of target - Recyclability rate calculation

Action 1: Identification of product-component's end of life treatment scenarios

According to different calculation methods, there are several pre-defined scenarios to treat about the waste. This action is to identify, one by one, the scenario of each product's component. Typically, [Rose C.M., 2000], [KEA, 2008] summarized that there are six different scenarios:

1, Product re-use → 2, Product remanufacturing → 3, Product material recycling after dismantling → 4, Product recycling without dismantling → 5, Energy recovery → 6, Landfill

[Eco d'EEE, 2008] further divided the dismantling process into two sub-scenarios: the de-pollution process (with specific treatment for hazardous components or materials) and the normal dismantling process (without specific treatment).

It's inefficient that all parts and materials should be dismantled. Just the mandatory parts (required by the laws and standards, etc.) and the components with higher economic or environmental benefits need to be priori treated. So the pre-analysis of dismantling targeted parts has to be done to identify the dismantling perimeter.

Sometimes, the designer doesn't have the sufficient knowledge to how to make the disassembly, so the product disassembly sequence evaluation or the real disassembly process test is necessary to prepare the identification of scenarios.

Inputs/Outputs necessary for this action

Input	Output
Product's bill of material	Environmental nomenclature of product's end of life
The pre-defined end of life treatment scenarios list	
Disassembly sequence evaluation result	

Tableau 55: Identification of product-component's end of life treatment scenarios

The competence necessary

- ✓ The knowledge of end of life treatment process
- ✓ The knowledge of product's dismentlability

Action 2: Calculation of product's recyclability rate

According to the identified treatment scenario of each component, the recyclability rate of each component could be calculated. The primary data from treatment center is preferred. This data is calculated basing on the real treatment process and the real material flow. If this type of data is not available, the secondary data is acceptable. The average data or the scientific research data might be used also. The existing tools provide also the rate references to support this calculation.

Inputs/Outputs necessary for this action

Input	Output
Environmental nomenclature of product's end of life	Product's recyclability rate
Product's recyclability rate calculating references	

Tableau 56: Calculation of product's recyclability rate

The competence necessary

- ✓ The knowledge of end of life treatment information of product

Action 3: Identification of the recyclability potential of material

The action is to support the further process for "recyclability rate improvement" which needs a priority analysis to identify the order of future improvement. The environmental benefits, the economic benefits have to be considered [Muthu S.S., 2012].

Inputs/Outputs necessary for this action

Input	Output
Product's recyclability rate	The product's recyclability potential of material
Environmental nomenclature of product's end of life	

Tableau 57: Calculation of product's recyclability rate

The competence necessary

- ✓ The knowledge of end of life treatment information of product
- ✓ The knowledge of the end of life treatment costing
- ✓ The environmental impacts analysis (Optional)

Action chain of the target: Design for recyclability

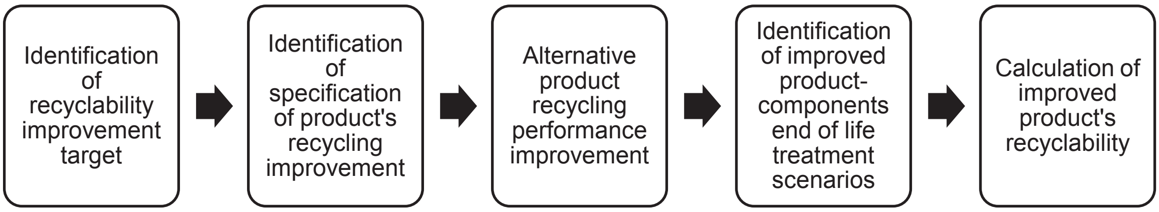


Figure 26: Action chain of target - Recyclability rate calculation

Action 1: Identification of recyclability rate improvement target

This action requires identifying the recyclability rate improvement target. This target could be presented in two formats: the absolute value or the comparative needs. The absolute value, such as achieve 50% of recyclability rate, etc., might consult the external requirements: the law’s requirements, ex: the WEEE required rate, the directive and the standards, ex: the eco label checklist, and the corporate objective. The comparative needs answer the eco-design requirements of actual product. To provide the end of life responsible product, the company or project defines this target, in the format: “Improve X% of recyclability rate comparing with actual product/similar product”, etc.

Inputs/Outputs necessary for this action

Input	Output
The product category	Product’s recyclability rate improvement target
The law’s requirement	
or international standard, directive or existing rate	
or corporate requirement	
or customer’s needs	

Tableau 58: Identification of recyclability rate improvement target

The competence necessary

- ✓ The knowledge of identification of objective

Action 2: Identification of specification of product's recycling improvement

Basing on the results of actual product’s recyclability rate and the improvement target, this action requires identifying a specification to fix the improvement items of product (ex: the structure has to be redesigned, the materials list should be replaced, etc.). Some guidelines could be considered into this action (ex: the VDI 2243 material computability table for recycling could be used here to identify the change of material, etc.) Some knowledge of disassembly (if existing or necessary, the specification of design for disassembly) could be involved to generate and complete the solution.

Inputs/Outputs necessary for this action

Input	Output
Product’s recyclability rate improvement target	Product’s recycling performance improvement specification
Product's recyclability rate	
Environmental nomenclature of product’s end of life	
If necessary, the disassembly specification	
Guideline (Specific knowledge)	

Tableau 59: I/O list of action - Identification of specification of product's recycling improvement

The competence necessary

- ✓ The knowledge of disassembly improvement
- ✓ The knowledge of compare the different scenarios
- ✓ The knowledge of product/structure/material

Action 3: Alternative product recycling performance improvement

According to the specification, the alternative researches will be done to resolve the concerned problems. To resolve these topics, some tools and information are necessary to provide the potential solutions. The previous calculation mechanism could alternative calculate and verify the new profits of these improvements.

Inputs/Outputs necessary for this action

Input	Output
Product's recycling performance improvement specification	Product's material recycling improvement

Tableau 60: I/O list of action - Alternative product recycling performance improvement

The competence necessary

- ✓ The knowledge of material recycling improvement of product
- ✓ The coordination and collaboration channels among different corporate functions

Action 4: Identification of improved product-component's end of life treatment scenarios

After the alternative eco-design, the product's material recycling profits have been improved. The main purpose of this action is to identify all necessary definition to describe the improved new product's life cycle situation. An improved environmental nomenclature of product's end of life will be released.

Inputs/Outputs necessary for this action

Input	Output
Product's material recycling improvement	Improved products environmental nomenclature of end of life

Tableau 61: I/O list of action - Identification of improved product-component's end of life treatment scenarios

The competence necessary

- ✓ The knowledge of end of life treatment process
- ✓ The knowledge of product's disassembly

Action 5: Calculation of improved product's recyclability rate

Inputs/Outputs necessary for this action

Input	Output
Improved products environmental nomenclature of end of life	Improved product's recyclability rate

Tableau 62: I/O list of action - Calculation of improved product's recyclability rate

The competence necessary

- ✓ The knowledge of end of life treatment information of product

Action chain of the target: Design for disassembly

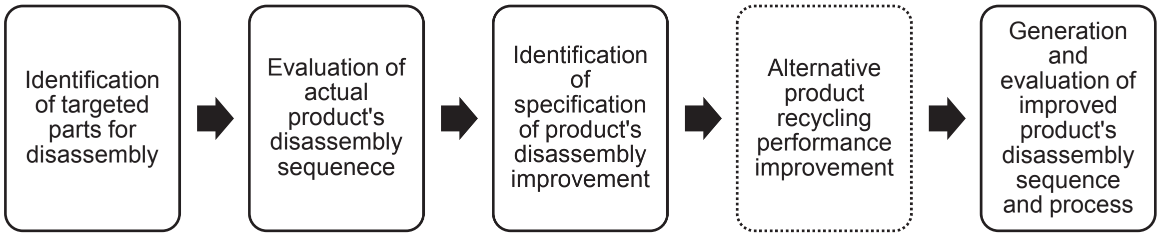


Figure 27: Action chain of target – Design for disassembly

Action 1: Identification of recyclability rate improvement target

This action requires the disassemble perimeter, which defines the list of constitution parts need to be disassembled. To generate this list, the environmental, technical and economic conditions and constraints should be considered.

Inputs/Outputs necessary for this action

Input	Output
The product category	Targeted parts for disassembly
Economic review (Second material marketing)	
Environmental impacts review	
or law, international standard and directive	
or corporate requirement	

Tableau 63: Identification of recyclability rate improvement target

The competence necessary

- ✓ The knowledge of legislation, standard and directive
- ✓ The knowledge of environmental impacts analysis
- ✓ The knowledge of material marketing information

Action 2: Evaluation of actual product's disassembly sequence

Depending on the targets list, an evaluation of actual disassembly sequence should be done to evaluate if the actual product design could ensure the requirements. And also, the operational situation needs to be added into the consideration, such as the operational efficiency (cost, time and facility, etc.) and the operational risks (Human health and environmental impacts etc.).

Inputs/Outputs necessary for this action

Input	Output
Targeted parts for disassembly	Evaluation results of actual disassembly sequence

Tableau 64: I/O list of action - Evaluation of actual product's disassembly sequence

The competence necessary

- ✓ The knowledge of disassembly technology
- ✓ The knowledge of compare the different scenarios
- ✓ The knowledge of product/structure/material

Action 3: Identification of specification of product's disassembly improvement

Basing on the evaluation results of actual disassembly sequence and the improvement target, this action requires identifying a specification to fix the improvement items of product (ex: the structure has to be redesigned, the materials list should be replaced, etc.). Some guidelines could be considered into this action.

Inputs/Outputs necessary for this action

Input	Output
Targeted parts for disassembly	Product's disassembly performance improvement specification
Evaluation results of actual disassembly sequence	
Guideline (Specific knowledge)	

Tableau 65: I/O list of action - Identification of specification of product' disassembly improvement

The competence necessary

- ✓ The knowledge of disassembly improvement
- ✓ The knowledge of compare the different scenarios
- ✓ The knowledge of product/structure/material

Action 5: Generation and evaluation of improved product's disassembly sequence and process

After the alternative eco-design, the product's disassembly profits have been improved. The main purpose of this action is to re-identify the new disassembly sequence with the description of the required tools. Finally, this information might to be used to prepare a "disassembly instruction" which guide the real operation, step by step for treatment center.

Inputs/Outputs necessary for this action

Input	Output
Product's disassembly improvement	Improved product's disassembly sequence and process

Tableau 66: I/O list of action - Generation and evaluation of improved product's disassembly sequence and process

The competence necessary

- ✓ The knowledge of end of life treatment process
- ✓ The knowledge of product's disassembly

Action chain of the target: Design for remanufacturing

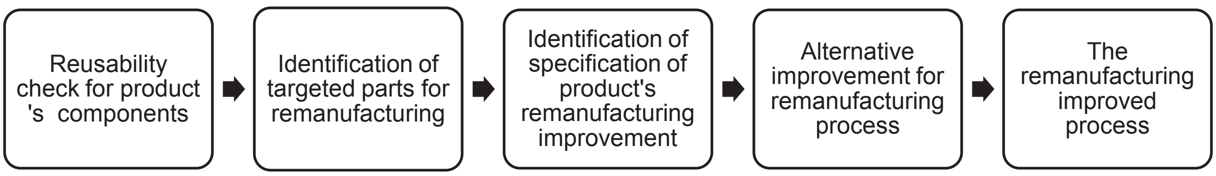


Figure 28: Action chain of target – Design for remanufacturing

Action 1: Reusability check for product's components

This action requires a reusability check for all products' components. This reusability lies on the corporate targets, the technical constraints, the technical success (Ex: a core components could be consulted to other new products) and the financial analysis. The remanufacturing is not an action only on project level, it needs the collaboration between the global support department, such as the supply chain, purchasing and internal strategy department to identify a corporate level plan.

Inputs/Outputs necessary for this action

Input	Output
Product	Component's reusability analysis
Product's constraints	
or common component/module analysis	
or Corporate planning	

Tableau 67: Reusability check for product's components

The competence necessary

- ✓ The knowledge of product/components

- ✓ The platform of standard module sharing

Action 2: Identification of targeted parts for remanufacturing

Mixing with the targets of disassembly, this action requires identifying a remanufacturing targeted components list.

Inputs/Outputs necessary for this action

Input	Output
Targeted parts for disassembly	Targeted parts for remanufacturing
Components' reusability analysis	

Tableau 68: Identification of targeted parts for remanufacturing

The competence necessary

- ✓ The knowledge of remanufacturing process
- ✓ The knowledge of environmental impacts analysis

Action 3: Identification of specification of product's remanufacturing improvement

This specification needs to include three parts: the requirements for disassembly, the requirements for extending some targeted modules' life time and the requirements for improving the remanufacturing process.

Inputs/Outputs necessary for this action

Input	Output
Specification to extend the product's life time	Specification of product's remanufacturing improvement
Identification of specification of product's disassembly improvement	
Targeted parts for remanufacturing	

Tableau 69: Identification of specification of product's remanufacturing improvement

The competence necessary

- ✓ The knowledge of remanufacturing process analysis

Action 4: Identification of Alternative improvement for remanufacturing process

According to the specification, the alternative researches will be done to resolve the concerned problems. To resolve these topics, some tools and information are necessary to provide the potential solutions. The previous calculation mechanism could alternative calculate and verify the new profits of these improvements.

Inputs/Outputs necessary for this action

Input	Output
Specification of product's remanufacturing improvement	Product's remanufacturing improvement

Tableau 70: I/O list of action - Identification of Alternative improvement for remanufacturing process

The competence necessary

- ✓ The knowledge of remanufacturing improvement of product
- ✓ The coordination and collaboration channels among different corporate functions

Action 5: The remanufacturing improved process

This action requires releasing an improved remanufacturing planning with the disassembly planning, the remanufacturing process and the logistic planning. The supply chain management is necessary to involve the remanufactured flow into the common component purchasing and supply flow.

Inputs/Outputs necessary for this action

Input	Output
Product's remanufacturing improvement	The remanufacturing improved process rate

Tableau 71: I/O list of action - Calculation of improved product's recyclability rate

The competence necessary

- ✓ The knowledge of documentation
- ✓ The knowledge of realization of corporate planning
- ✓ The coordination and collaboration channels among different corporate functions

Design for recoverability reference

Existing recyclability rate calculation approaches

There are several proposals to calculate the product’s recyclability rate and identify the potential of material. Between the different proposals, the mechanism is not similar. The next paragraphs present three examples.

1. Recyclability rate calculation by ABB Corporation

This is a simple and generic semi-quantitative approach to calculate the recyclability rate. This approach just focuses on if this component or material has been recycled. If actually, it exist the end of life treatment process for such component or material, the recyclability rate equals 100%; if not, the rate is noticed as 0%.

This result is poor and insufficient to support the further improvement, but it’s useful to help the company to verify the status of treatment of their product and it highlights the needs to sign the new contract with treatment center to recycle their product.

2. Eco D’EEE recoverability rate calculation

This is a quantitative approach to calculate the product’s recyclability rate [Eco d’EEE, 2008]. This tool, developed by the CODDE society, targets the domain of electric and electronic equipment, but its data reference could also be used to other industrial area. At first, this approach defined the chain of treatment activities as some scenarios:

1, Product re-use → 2, product material recycling after the depollution process → 3, Product material recycling after dismantling → 4, Product recycling without dismantling → 5, Energy recovery → 6, Landfill

The “depollution” is a dismantling process, which requires some specific treatment process, for some hazardous materials or component.

For each scenario, the Eco D’EEE approach provides a list of recyclability rate of certain materials and electronic and electric components.

		After Dismantling (AD)			After shredding (AS)				
	Material / component	Recycling Potential (AD) - t_{CYCD}	Energy Recovery Pot. (AD) - t_{COVD}	Residual Waste Pot. (AD) - (100% - t_{CYCD} - t_{COVD})	Recycling Potential (AS) - t_{CYCG}	Energy Recovery Pot. (AS) - t_{COVG}	Residual Waste Pot. (AD) - (100% - t_{CYCG} - t_{COVG})	Type of data quality	Sources
Polymers	ABS	94%	1%	5%	74%	1%	25%	One-off for AS data. Hypothesis EcoDEEE for energy recovery	(Mathieux, JoCP, 2008; ENSAM, 2002; PlasticsEurope 2006ab; PlasticsEurope, 2008)
	ABS with any additives	94%	1%	5%	0%	5%	95%		
	HIPS	94%	1%	5%	83%	1%	16%		(Mathieux, JoCP, 2008; ENSAM, 2002; PlasticsEurope 2006ab; PlasticsEurope, 2008)
	HIPS with any additives	94%	1%	5%	0%	5%	95%		
	PP	94%	1%	5%	90%	1%	9%		(Mathieux, JoCP, 2008; ENSAM, 2002; PlasticsEurope 2006ab; PlasticsEurope, 2008)
	PP+EPDM	94%	1%	5%	90%	1%	9%	Extrapolated from "PP" for AS data. Hypothesis EcoDEEE for energy recovery	(Mathieux, JoCP, 2008; ENSAM, 2002; PlasticsEurope 2006ab; PlasticsEurope, 2008; Froelich, 2007)
	PP-GF	94%	1%	5%	90%	1%	9%	Extrapolated from "PP" for AS data. Hypothesis EcoDEEE for energy recovery	(Mathieux, JoCP, 2008; ENSAM, 2002; PlasticsEurope 2006ab; PlasticsEurope, 2008; Froelich, 2007)
	PP with any other additives	94%	1%	5%	0%	5%	95%	One-off for AS data. Hypothesis EcoDEEE for energy recovery	(Mathieux, JoCP, 2008; ENSAM, 2002; PlasticsEurope 2006ab; PlasticsEurope, 2008; Froelich, 2007)
	P/E	94%	1%	5%	90%	1%	9%	Extrapolated from "PP" for AS data. Hypothesis EcoDEEE for energy recovery	(Mathieux, JoCP, 2008; ENSAM, 2002; PlasticsEurope, 2006ab; PlasticsEurope, 2008; Froelich, 2007)
	PC, ABS-PC, PA, PA-6, HDPE, SAN with, or without additive	94%	1%	5%	0%	5%	95%	Extrapolated from ABS for AD data	(ENSAM, 2002 ; PlasticsEurope, 2006a; PlasticsEurope, 2008)
	Other Polymer	0%	5%	95%	0%	5%	95%	One-off data	(ENSAM, 2002)
	Polymers in PWB	0%	95%	5%	NR	NR	NR	One-off data	(Mathieux, JoCP, 2008)
	Steel	95%	0%	5%	95%	0%	5%	Hypothesis EcoDEEE	(ISI, 2006; Russo, 1999)
	Aluminium	93%	0%	7%	91%	0%	9%	Statistics	(Boin & Bertram, 2005)

Figure 29: The recyclability rate reference proposed by Eco D'EEE project (Part)

According to this definition, the users need to identify the treatment scenario for each component or material. By consulting with the tare reference list, the user could directly notice the recyclability rate of each component, and the whole product.

3. Recyclability Potential Index (RPI)

This tool targets the textile industry, but the approach could be sharable to other area. This tool proposes a concept for the Recyclability Potential Index (RPI) of textile fibers considering their environmental and economic gains from the recycling process and also attempts to quantify the Recyclability Potential Index (RPI) of ten common, widely used textile fibers [Muthu S.S., 2012].

The calculation mechanism is shown as follow equations:

The concept of Recyclability Potential Index (RPI)
$RPI = EGI_1 + EGI_2$
The concept of Environmental gain Index (EGI_1)
$EGI1 = X_1 + X_2 + X_3 + X_4$
Note: - *X_1 is the saving potential resource* - *X_2 is the environmental impact caused by producing virgin fibers* - *X_3 is the environmental impact due to land filling* - *X_4 is the environmental benefits gained out of recycling versus incineration*
The concept of Economic gain Index (EGI_2)
$EGI_2 = Y_1/Y_2$
Notes: - *Y_1 is the price of recycled fiber* - *Y_2 is the price of virgin fiber*

Tableau 72: The calculation equation of RPI [Muthu S.S., 2012]

To calculate this RPI, some life cycle analysis should be done to prepare the related data, such as the environmental impact caused by producing virgin fibers and the environmental impacts due to land filling, etc. So some LCA software is required.

The [Ardente F., 2003] proposed a similar mechanism which defines the "Global recycling Index" by three indexes: The EEI (Energy & Environmental Index), ESI (Economic Index) and TSI (Technological Index).

Existing tools of "Design for material recycling" and "Design for disassembly"

Several tools support the "design for material recycling" and "design for disassembly" are proposed. According to the different needs and the focused area, these tools evaluate and analyze different characteristics and propose the improvable guideline. The following table summarizes some collected tools:

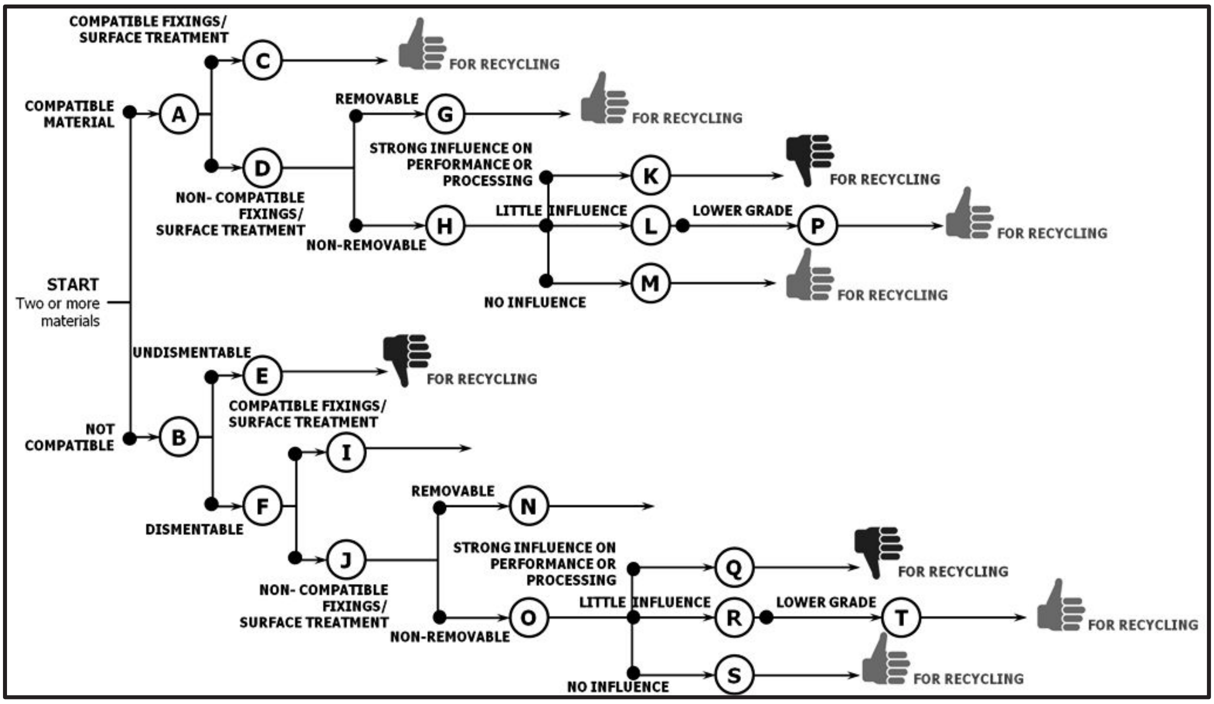


Figure 30: Checklist of recyclability from the compatibility between materials (Source [Chiodo J., 2005])

Name	Proposal	Description	Reference
Eco D'EEE	End of life	Guideline of disassembly and recycling improvement	[CODDE, 2008]
Thermoplastic material compatibility for recycling	End of life – material recycling	Compatibility table for recycling (between thermoplastic materials)	[VDI 2243 2002]
Recycling oriented design	End of life - recycling	A case study of household appliances recycling design	[Kang H.Y., 2001]
Design for disassembly guideline	End of life	Guideline to guide the disassembly and recycling improvement	[Chiodo J., 2005]
ENDLESS Model	End of life	Global recycling index to alternative evaluate different parameters in line with recyclability	[Ardente F., 2003]
Design for product lifetime	End of life	Multi guidelines group for disassembly, remanufacturing,	Autodesk website[1]

		update, recycling and repair	
Disassembly evaluation software	End of life - disassembly	Computer-based methods to identify the "disassemblability" by analyzing the process parameter levels, times, costs and sequence	[Hesselbach, J., 1998]
Disassembly evaluation rating scheme	End of life - disassembly	Quantitative/alternative evaluation of sequences	[Kroll E., 1996]
Manufacturability evaluation for disassembly	End of life - disassembly	Manufacturability impacts on product's disassembly	[Kroll E., 1999]
Cost analysis of disassembly	End of life - disassembly	The cost evaluation and guidelines	[Kuo T.C. 2000]
Fastening and joining selection	End of life - disassembly	Quantitative calculation / software for selection of most economical joining method	[Shu L., 1999]
Disassembly times evaluation	End of life - disassembly	Time-based numeric indices to each design factor to determine the disassembly time of a product	[Desai A., 2003][a] [Desai A., 2003][b]
Notes: 1. *http://sustainabilityworkshop.autodesk.com/media/engineers/resource/DfLifetime_QuickReferenceGuide_AdskSustainabilityWorkshop_large.pdf*			

Tableau 73: The existing tools support "Design for recycling" and "design for disassembly"

Existing tools of "Design for remanufacturing"

Tools	Format	Key Purpose	Feature	Author(s)
Component reliability assessment	Quantitative Calculations	Remanufacturing strategy decision making	Customer focused Process oriented	[Zhang T., 2010]
DfRem guidelines	Qualitative Reference	Guidance	Simple Offers guidance	[Ijomah W., 2007[a]] [Ijomah W., 2009]
DfRem metrics	Quantitative Calculations/ software	Assess of remanufacturability	Process oriented Familiar concept	[Bras, B., 1996] [Amezquita, T., 1995]
DfRem metrics	Quantitative Calculations/ software	Assess remanufacturability Suggest improvements	Lifecycle thinking. Offers guidance	[Willems, B., 2008]
Energy comparison tool	Quantitative Calculations	Compare manufacture and remanufacture energy usage	Lifecycle thinking	[Sutherland J., 2008]
Hierarchical decision model	Quantitative Calculations	Design of product architecture for most profitable disassembly	Lifecycle thinking	[Lee H.B., 2010]
MCDM	Qualitative	Multi-criteria	Offers guidance	[Jiang Z.G., 2011]
RemPro matrix	Qualitative Reference	Guidance, prioritization of issues	Simple Offers guidance	[Sundin, E., 2004]
REPRO2	Qualitative Software	Decision making, providing past examples	Early in design process No required extensive knowledge. Offers guidance	[Zwolinski, P., 2008] [Zwolinski, P., 2006] [Gehin, A., 2008]
RDMF	Qualitative	Remanufacturing	Process oriented	[Subramoniam

		Decision-Making Framework Questions	Simple Offer s guideline	R.,2011]

Tableau 74: The summary of "design for remanufacturing" tools aids in the literature (Some judgments from the source: [Hatcher G.D., 2011])

Main concerned product's or process's items

The "Design for material recycling" and "design for disassembly tools" focuses on the following environmental-concerned items:

Material selection				
EASY RECYCLED[10]	LABEL MATERIAL[4]	MINIMUM ADDITIVIES	COMPATIBLE SURFACE TREATMENT[7]	HAZARDOUS MATERIAL FREE[8]

Material combination		
EASY TO SEPARATE[1]	MATERIAL COMPATIBLE[5]	MINIMUM MATERIAL TYPES[9]

Component & Module					
MODULARIZATION[11]	EXTENDING OF LIFE TIME	EASY TO REPAIR	EASY TO CLEAN		

The removable structure of product					
PART ACHIEVEABLE[6]	REMOVABLE STRUCTURE[2]	MINIMUM DISASSEMBLY TOOLS	MINIMUM TREATER NUMBER	MINIMUM PART SIZE	MINIMUM DISASSEMBLY TIME

Corporate process management	
SUPPLY CHAIN MANAGEMENT[12]	STOCK MANAGEMENT[13]

Collaboration with end of life treatment center		
EASY TAKE-BACK SYSTEM	DATA TRANSFER FROM TREATER	INSTRUCTURE FROM DESIGNER[3]

Notes:

1. *Easy to separate means the materials could be easily separated in shredding process.*
2. *Without the non-separable joints; easy determinate the joint points; Disassembly-oriented fasteners; this removable structure is strongly required for hazardous, toxic or not conventionally recyclable parts.*
3. *The instruction, named as the end of life instruction, list the requirements of collection and separation phases, the proposal of disassembly sequences and tools, the list of hazardous, toxic and specific components and the warming during the treatment process.*
4. *The ISO 11469 Plastic code; ISO 1043; 67/548/EEC & IARC carcinogenic substances; 97/129/EEC for package*
5. *The compatibility table is from Germany VDI 2243 Part 1*
6. *The enough space to separate*
7. *The surface treatment includes the paint and other technologies; the metallic coating is not recommended.*
8. *Includes lead, cadmium, mercury, etc.*
9. *The homo-polymer, copolymer or pure metals are preferred for the parts which is heavier than 25g*
10. *The recycling process and method is available everywhere.*
11. *The modularization is required by the remanufacturing. This requirement easily leads to the conflict with other "easy separation" criteria.*
12. *The recycled and remanufacturing material / components need to be considered as a new purchasing of new product. The purchasing process should be involved into the global supply chain system.*

13.	*If the remanufacturing is charged by the product providers, the stock of disassembled parts needs to be considered.*

Tableau 75: Product/process items of “Design for material recycling” and “Design for disassembly”

(Sources: [Auto desk], [VDI2243, 2002], [Van Schaik A., 2004], [Perry N., 2012], [Kuo T.C., 2001], [CODDE, 2008], [Dowie T., 1994], [Masanet E., 2002], [Santochi M., 2002], [Alting L., 1995], 25 Type I Eco label checklist and requirements)

Sustainable supplier management

Supply chain is a system of organizations, people, technology, activities, information and resources involved in moving a product or service from supplier to customer. The green supply chain is to indicate the supply management activities that attempts to contribute to the sustainable performance of all traditional and related-extended supply activities [Beamon B.M., 1999]. Beside of traditional criteria, [Hassini E., 2012] identified that the sustainable supplier managements should consider also the sourcing and material environmental impacts, the transport scenarios, especially, the GHG emission and the recycling performance. In order to make a holistic analysis and management, the supply chain management needs to collaborate with all corporate functions.

Greening purchasing and supply management relies on the deployment of relevant supply management capabilities and methods.

Two main categories of green supply might be identified to classify them [Bowen F., 2001], [Seuring S., 2008]:

- Supplier management for risks and performance based on “Greening the supply process”

To answer the external pressures, the first manner is to set up an environmental management system of supply chain to avoid the environmental related risks [Green Peace, 2011]. This management system requires some minimum criteria (in accordance with the external pressures) to monitor, evaluate and report the supplier’s process and its global performance [Caniato F., 2012], [Seuring S., 2008]. In order to complete the data, the environmental audit for flow system including the manufacturing process, and the organizational performances is required to be more detailed. Then, these environmental performances are seen as the prerequisites for suppliers that range and allow them to provide materials or service(s) to operate as part of the supply chain [Lamming R.C., 2005], [Min H., 2001]. [Büyüközkan G., 2011] pointed that the “incomplete” information is a great risk to affect the efficiency of evaluation, so they provides an approach basing on the fuzzy analytic network process within multi-person decision-making schema under incomplete preference relations.

In this category, the regulation and normal standards play an important role. They mainly focus on the certification of ISO 140001 and EMAS. To obtain these certifications, some activities, such as the monitoring of daily processes and the evaluation of supplier’s environmental management system, are established. Then, the corporate questionnaire, which is sent to suppliers for self-audit, are usually mentioned into the papers [Baumann H., 2002]. This self-audit indicates how the supplier deals with environmental issues and how it collects data and declares the results. Thirdly, enterprises have to take a longer part of the supply chain into account to allow an improvement in the supply relations as well as in the performance. A company-overlapping communication and a strategic training to improve the supplier’s performances are usually proposed [Seuring S., 2008].

Besides of above mentioned traditional activities of supply chain, according to environmental challenges, some extended activities are appearing; such as the relationship with recyclers and remanufacturers to involve the recycled materials into the normal supply flow. [Beamon B.M., 1999] indicated that these activities and related material flows should be embedded into management system.

- Supply chain management for sustainable products based on the “Product based green supply”

A manner to contribute to the needs for “Eco design” is to set up a product life cycle management to require, train and cooperate with suppliers. In order to realize a “sustainable product”, the competence of suppliers plays an important role. Supplier developments are required before enterprises are even able to offer sustainable products to their customers. For example, textile and apparel producers/retailers have to make sure there is an organic cotton supplier before they are able to offer such products [Kogg B., 2003], [Goldbach M., 2003]. To keep a long term relationship with suppliers, a training and cooperation on product level are considered as a key part. In this case, these communications not only require an exchange among supply chain on process level, but also on product level, when some deeper technical information should be translated [Caniato F., 2012], [Handfield R., 2005].

In this category, the LCA or LCA-related methods are usually mentioned to support the company to address the eco design related issues and necessary information. [Nakano K., 2006] illustrated a framework to make the business partners collaboration for green product developing. This framework requires the life cycle data transfer between the companies with its suppliers.

The additional condition is the corporate definition of “Eco design” which pre-indicates the goal and boundaries of the cooperation. The project’s buyer, delegate the project team, keeps the real contact and cooperation with suppliers to achieve specific project’s goal.

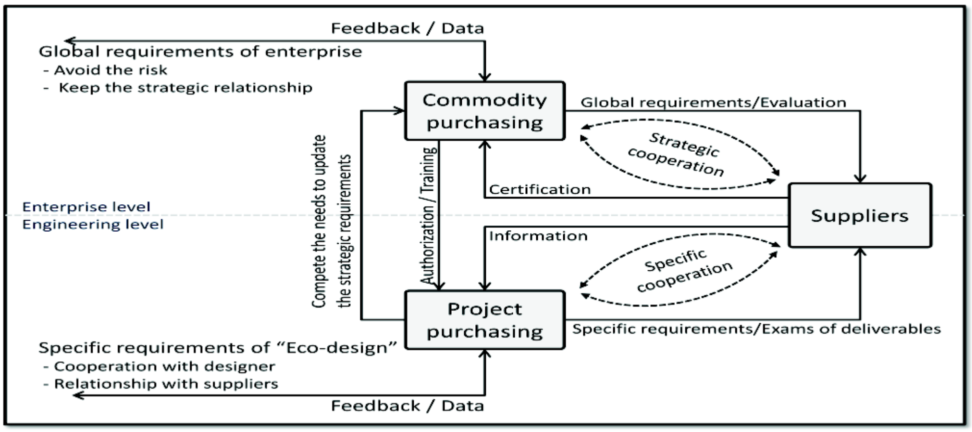


Figure 31: Relationships among the eco-activities of supply chain

The figure X summaries the relationships as above mentioned between the enterprise and its suppliers. Commodity purchasing department delegates the enterprise to direct contact with suppliers to keep a long term strategic relationship. This figure shows that the two categories are not mutually exclusive. There is a positive relationship between the two above categories to accelerate and complete the environmental performance [Bowen F., 2001], [Seuring S., 2008]. The selection of eco design methods should involve the consideration of the acts of two categories and their internal relationships to make the coherence.

Example tools to support the process-oriented environmental management

WWF textile supplier certification

Before the purchasing and collaboration process, the environmental certification of the supplier is necessary to be demanded which might support the company to control the environmental performance of whole supply chain. For textile industry, WWF proposed a set of qualitative evaluation questions to measure the supplier’s environmental management situation. This evaluation list includes five main categories of questions, likes the global issues of management system which monitors and controls the significant manufacturing processes, the “traceability” of environmental related data and documents, the energy using, the water using and pollution and the fifth, emission in air. For each category, a list of questions is provided and noted the score (three options: Insufficient (-1 point), acceptable (+ 0.5 point) and sufficient (+1 point)) according to supplier’s answer. After summarizing the scores, this WWF evaluation list proposes the company could prioritize the suppliers with the scores from 21 to 32 points. For suppliers with the scores from 1 to 21, The WWF suggests that the companies might accompany with them to improve their environmental management system by requiring the more legible environmental targets, requirements and data etc. For rest suppliers (score is less than 1 point), the WWF thinks that their environmental management system is in sufficient and this supplier need to implement immediately the EMS or involve the external auditors to complete the data necessary.

Process-oriented environmental management system

The process-oriented EMS - environmental management system is usually used to manage and resolve the environmental problems of manufacturing facilities. The application of EMS could gain both the environmental and cost saving performance. [Lo C.K.Y, 2012] analyzed the financial performance in fashion and textiles industries. The results show that beside of environmental gains, the direct operational cost and some indirect potential risk could be synchronously reduced. ISO standards [ISO 14001, 2004], [ISO 14011, 1996] play the most important role in this area. The European “environmental management and audit system” [EMAS, 2001] directive, British standard BS7750 [BS7750, 1994] and Canadian “Responsible Care” are also often mentioned. These above four standards require the manufacturing facilities to monitor, register, manage and improve all environmental related data. EMS also intends that the enterprise should set up their management organization to continuously deal with their environmental issues.

By analyzing these four above common standards, there are some similarities and differentia:

Similarities	Differentia
- The same final objective: improvement of environmental performance of factories' actions - Similar structure and topics: ✓ Environmental Management System ✓ Preparatory Environmental Review ✓ Environmental Policy ✓ Organization and Personnel ✓ Environmental Effects/ Aspects ✓ Objectives and Targets ✓ Environmental Management Programs ✓ Manual and Documentation ✓ Operational Controls ✓ Records ✓ Audits ✓ Management Review ✓ Environmental Statement (EMAS only) - The documentation requirements to register all related information and decision - Three-party independent audit	- Different geometrical perimeter. - Different industrial targets (“Responsible Care” focuses on chemical industry) - ISO 14001 can be used in all types of organization, but three others are just for industry or factory. - EMAS and BS 7750 is a legislation which defines the environmental improvement targets, relate indicators and the guidelines. But ISO 14001 emphasizes the regulation of documentation and the management system. - EMAS require the environmental declaration and statement for all special indicators.

Tableau 76: Comparison between different environmental management systems

According to “ISO 14001” standard, the working process of environmental management system is based on PDCA approach:

- Plan: establish the objectives and processes necessary to deliver environmental improvement results in accordance with the organization's environmental policy.
- Do: implement the processes.
- Check: monitor and measure processes against environmental policy, objectives, targets, legal and other requirements defined in “plan” phase, and register and report the results.
- Act: take actions to continually improve performance of the environmental management system.

In the “plan” phase of ISO 14001, the initial review or gap analysis is recommended. This analysis focuses on the actual situation of the facilities used and all related elements of operational processes (the inputs / outputs / discharges and noise, dust, heart and VOC, etc) which might interact with the environment [Martin R., 1998]. According to this review, two categories of actions could be launched, [Tibor, 1996]:

- The improvement of global environmental performance

To answer the local environmental protection needs and to contribute to the global performance of factory or company, The IPPC European Directive 96/61/EC requires considering in particular the following, giving regard to the likely costs and advantages of measures and to the principles of precaution and prevention:

- Use of low-waste technology
- Use of less hazardous substances
- Furthering of recovery and recycling of substances generated and used in the process and of waste, where appropriate
- Comparable processes, facilities or methods of operation, which have been tried with success on an industrial scale
- Technological advances and changes in scientific knowledge and understanding
- Nature, effects and volume of the emissions concerned
- Commissioning dates for new or existing activities
- Length of time needed to introduce the best available techniques
- Consumption and nature of raw materials (including water) used in the process and their energy efficiency
- Need to prevent or reduce to a minimum the overall impact of the emissions on the environment and the risks to it
- Need to prevent accidents and to minimize the consequences for the environment
- Information published by the Commission of the European Communities pursuant to any exchange of information between Member States and the industries concerned on best available techniques, associated monitoring, and developments in them, or by international organizations, and such other matters as may be prescribed.

These above evaluated indicators are based on the global level. The evaluation results might cover several activities from different production line. And the improvement targets and requirements affect also the environmental performance of related production line which will be defined in next category.

- The improvement of certain manufacturing processes

According to the global improvement planning and some specific requirements of production from eco design, there are certain actions which focus on the improvement of the product manufacturing process. Based on the LCA of products, some new technologies are identified as new solutions to optimize the environmental impacts of certain manufacturing actions [Niennien E., 2007]. Above topics or evaluation indicators of the first category could be used also for this improvement. But some operational topics and indicators of production process are decided by the designer [ErP directive, 2005], such as the selection of input materials, the definition of production manners, etc. So a relationship between the manufacturing faculties and eco design is necessary to accelerate this improvement. Inversely, the improvement of manufacturing process contributes also to the eco design results which are developed by design team.

[Dave G., 2010], through analyzing 52 samples of product and clothing product, suggests that bioassays and toxicity tests should become an integrated part of textile environmental quality improvement process.

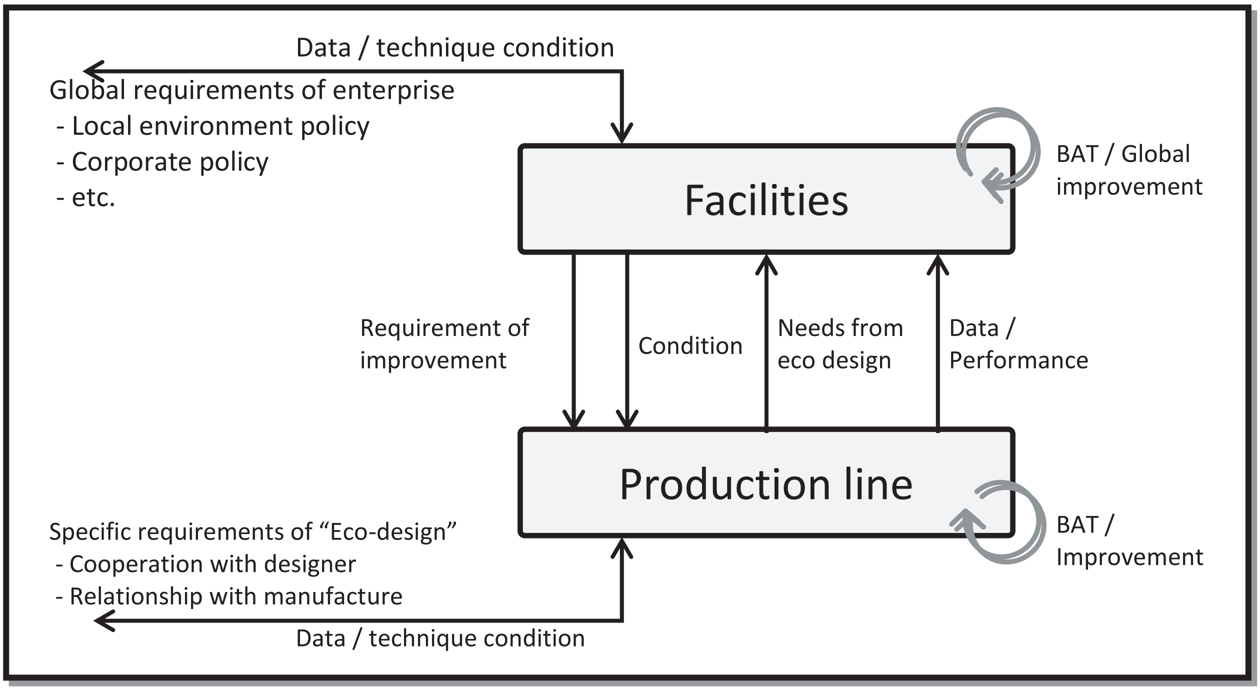


Figure 32: the summary of relationships among the eco-activities of production facilities

Figure 32 summaries all above mentioned relationships between the improvement of facilities performance and the improvement of some production line, which has a direct relationship with eco design practices. On one side, the needs of facilities provide the general constraints and the requirements of environmental improvement in manufacturing area to each production line. With the deployment of BATs - Best Available Technologies at facilities level, it also modifies the environmental conditions for each eco design practices. On the other side, the eco design practices make same optimization of its production line, which directly changes the performance of facilities. So an analysis of all relationships has to be developed to have a suitable selection of eco design activities.

Existing tools to support the process-oriented environmental management

EMAS

EMAS, is a voluntary "European Eco-Management and Audit Scheme" for continuously improving the environmental performances of company. This scheme provides a standard tools kit and related operational process to measure, evaluate, organize, manage, report and improve environmental issues and publish the creditable information for these issues [EMAS Website]. Typically, EMAS system could support the achievement of:

- Environmental regulations/laws compliance and relief
- Risk minimisation of operational procedure
- Better management of resource for cost reduction
- Improvement of the relationship with internal/external stakeholders

In order to ensure the achievement of above objectives, six significant environmental indicators are highlighted to be considered:

- Energy Efficiency: *the total energy consumption, the total reusable/ renewable energy use*
- Material Efficiency: *annual mass-flow of different materials used*
- Water: *total annual water consumption*
- Waste: *annual generation of waste, annual generation of hazardous waste*
- Emission: *annual emission of toxic, acidify, green housing and others impacts-generated gas*
- Biodiversity: *use of land*

EMAS is compliant with “ISO 14001” standard, which fulfils a systemic “PDCA” approach to organize all related working processes.

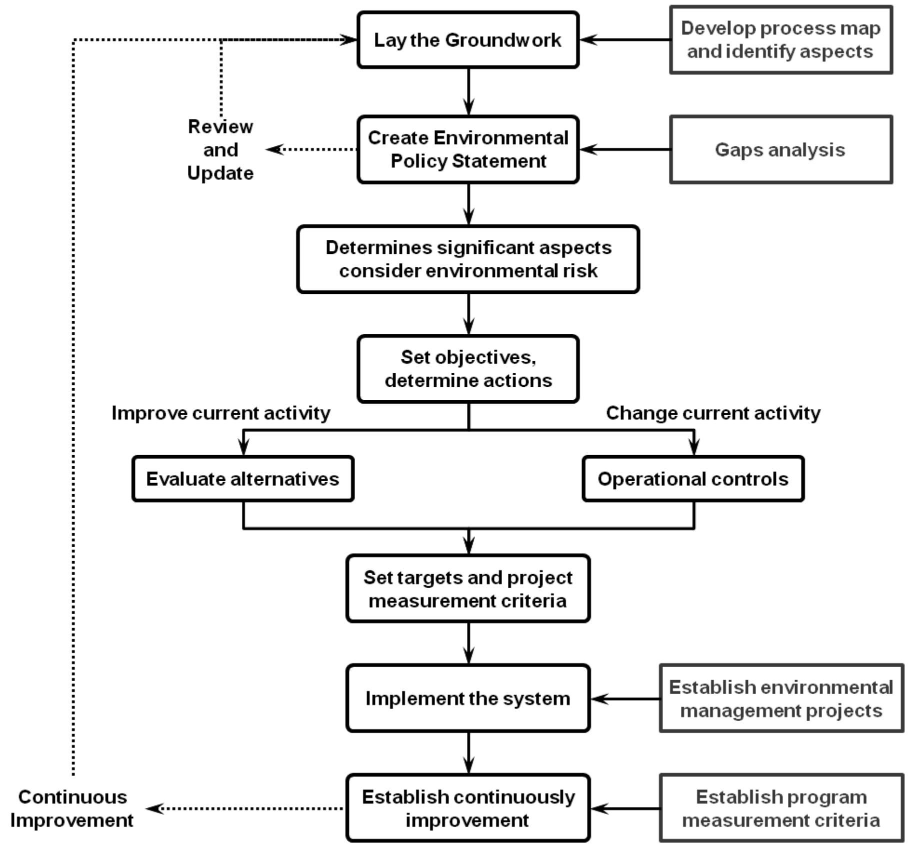
<table>
<tr><td rowspan="2">Plan</td><td>Environmental review
▪ Actual operational procedure review
▪ Actual resource using management
▪ Actual energy using management
▪ Actual waste treatment
▪ Actual emission summary</td><td>Environmental management, all departments
Involved</td><td rowspan="2">Do</td><td rowspan="2">Environmental programme
▪ Structure
▪ Responsibility
▪ Training
▪ Communication</td><td rowspan="2">Environmental management</td></tr>
<tr><td>Environmental policy
▪ Environment committee
▪ Identify the improvement objectives and sub-targets</td><td>Top managers, Environmental management
Involved</td></tr>
<tr><td rowspan="3">Check</td><td>Environmental management system
▪ KPIs Monitoring
▪ Environmental impacts measure
▪ Record and documentation</td><td>Environmental management, Process management, All departments Involved</td><td rowspan="3">Act</td><td>Management review</td><td rowspan="3">Environmental management, Top management, all departments Involved</td></tr>
<tr><td>Environmental statement
Registration and use of EMAS logo</td><td>Environmental management</td><td rowspan="2">Continuous improvement</td></tr>
<tr><td>Environmental audit
▪ Third party audit / Auto-audit</td><td>EMAS environmental verifier(s)</td></tr>
</table>

Tableau 77: The management process and involved departments of EMAS

IEMS

“Integrated Environmental Management System” (IEMS) published by United States Environment Protection Agency in 2001. IEMS used the “ISO 14001” standard as a start point and it particularly illustrated the details of the steps to implement the EMS involve some technical work, such as identifying and prioritizing environmental concerned issues, evaluating options for addressing those issues, and the measuring of success of implementing those options. Beside of those technical works, the details of administrative procedures and related tools have been proposed to ensure the following up of the implementation process [EPA, 2001].

This IEMS system classified related actions into 9 sub-modules to ensure the entire integration of EMS in company.



Module 1: Laying the Groundwork
This module focuses on two axes of preparation to answer the following questions: ▪ Why does this company need to implement the environmental management system? For this question, this module proposed a comprehensive discussion among all hierarchical levels and functions of company to answer what an IEMS is and why the company should develop one. ▪ What are significant environmental issues of this company? For this question, this module supports the initiation of current environmental impacts summary for company entity, product, processes or services.
Module 2: Creating an Environmental Policy
The module requires the company to review and assess the performance of current methods and tools for managing the environmental issues collected into first module. According to the “Gap analysis” of corporate importance, the top management and environmental department will define the corporate environmental policy and decide the scope of the IEMS.
Module 3: Determining Significant Environmental Aspects and Setting Objectives
The module 3 provides a semi-quantitative tool to determine the significant environmental aspects and prioritize them. Secondly, this priority will be translated as the objectives of environmental improvement.
Module 4: Evaluating Alternatives
IEMS system provides a method to consider a hierarchy of alternatives to prepare the solution which will meet the objectives predefined in module 3. These alternatives might include the different working area, such as the material using, the pollution prevention and waste management.
Module 5: Setting Targets and Measuring Success

The module 5 requires the company to establish a set of specific targets to ensure the achievement of environmental objectives for those significant environmental impacts. A measuring system is necessary also to evaluate the final results.
Module 6: Developing Operational Controls
The operational control system is necessary to certain environmental aspects, which require a operational procedure, step by step, to achieve the improvement. This controlling system could ensure the action chain is preformed in a right way. The module 6 guides the company how to develop this controlling system when necessary.
Module 7: Implementing IEMS
The module 7 guides the company to make a planning for IEMS development process.
Module 8: Building Organizational Support
The collaboration among the whole company and the documentation are very important to judge the long-term success of environmental management. The module 8 lists the necessary actions to support the organizational building inside or outside of company. Those actions include the inter- or extern-communication, training, seminar and meeting and the stakeholder involvement.
Module 9: Establishing Continuing Improvement
To ensure success and continuing improvement, regular reviews of overall IEMS are necessary. The module provides the critical information to ensure the IEMS continuing improvement.

Tableau 78: Working process and modules of IEMS system (Source [EPA, 2001])

The working volume of each module depends on the working scope that defined in first step. It’s not necessary to integrate the IEMS in all operational activity, especially for the first implementation. The significant environmental issues and the related main actions could be firstly considered. Along with the enrichment of operational experiences for daily actions, the detailed IEMS might be developed further.

Best Available Techniques – BAT

To answer the requirements from two above categories, the “Best Available Techniques” – BAT is required and it must be applied in company. The BAT is

> “most effective and advance stage in the development of an activity and its methods of operation, which indicate the practical suitability of particular techniques for providing, in principle, the basis for emission limit values designed to prevent or eliminate or, where that is not practicable, generally to reduce an emission and its impact on the environment as a whole.”
> --- European 96/61/EC directive
>
> Where:
>
> - *B, “best” means this technology is most effective in achieving a high level of environmental protection.*
> - *A, “available” means the advantage, economic, operational and implementable issues have been considered to ensure the realization.*
> - *T, “techniques” includes both the technology used and the way in which the installation is designed, built, managed, maintained, operated and decommissioned.*

At the company or factory level, the identification of most effective techniques must depend on the local factors, such as the corporate analysis for the benefits and costs of each available option. The choice may be justified on:

- The geographical location
- The technical characteristics of the installation/facility
- The economic and technical viability of upgrading existing installations

Beside of the official BAT, there are some original researches to improve the environmental performances of production process. These researches focus on and propose the new technologies for certain production activities.

Existing tools of “Best Available Technology”

European Union published a Reference Document on Best Available (BREF) for each sector. This document provides general information on different sector and on the industrial processes used. It provides data and information concerning emission and consumption levels and describes the emission reduction and other techniques that are considered to be most relevant for determining BAT and BAT-based permit conditions.

BREF for textile and clothing industry: http://eippcb.jrc.es/reference/BREF/txt_bref_0703.pdf

Beside of BREF, Ireland Environment Protection Agency published also some BATs: http://www.epa.ie/downloads/advice/bat/

The following table summarizes some other original new techniques (examples) for improving the environmental impacts of certain production activities of textile industry:

> [Hasanbeigi A., 2012] make a literature review (more than 140 articles) of energy efficiency and energy using technologies for the textile industry. Final 184 different technologies have been collected and classified into four general steps:
>
> - Spun yarn spinning
>   - Weaving
>   - Wet-processing (preparation, dyeing, printing, and finishing)
>   - Man-made fiber production
>
> For each technology, the electricity saving, the capital cost (US$) and the Payback period (year)

have been analyzed and listed.
[Robinson T., 2001] make a review for eco-friendly technologies to control the waste-water pollution due to the "dye" process. In this article, the technologies have been classified into three general categories: ▪ The chemical methods ▪ The physical treatment ▪ The biological treatment [Dos Santos, 2007] a review focuses on anaerobic technology [Verma A.K., 2007] a review focuses on chemical coagulation/flocculation technologies [Lau W.J., 2009] a review of Preparation, performance evaluation, transport modeling, and fouling control of waste treatment
[Sivakumar V., 2001] summarized the eco friendly technologies in leather processing. Deeply, there is a detailed analysis of the use of ultrasound as a tool to improve the cleanliness of leather production for each stage.
[Kandilli C., 2011] presented a waste heat recovery system for textile industry, especially, for dye process. This waste heat recovery could enhance the energy efficiency during the production process. [Zabaniotou A., 2010] presented that the waste from the cotton ginning house can be used as an alternative energy source for reduction of GHG emissions in the textile industry.
[Cagno E., 2005] analyzed 134 "pollution prevention" cases to improve the environmental performance of production systems. The key element of "the pollution prevention approach" is the 'reduction at source' principle, derived from the idea that the generation of pollutants can be reduced or eliminated by increasing efficiency in the use of raw materials, energy, water and other resources. The recycling approach (in-process recycling, on-site recycling and off-site recycling) are also considered.
[Nieminen E., 2007] provides the guidance for the list of best available technologies in textile industry. Those BATs are proposed depending on the life cycle assessment.

Tableau 79: several examples of BAT in textile industry

Process-oriented Life cycle assessment

The process-oriented life cycle assessment is a quantitative technique to analyze the life cycle environmental impacts associated with all processing actions in an organization boundary. According to different needs, the perimeter of the processing actions could cover the manufacturing process, using/service process (such as the cleaning, the maintenance/Installation actions, etc.) and the waste treatment process. This assessment could be addressed to both product-based process (the related production line and process analysis for certain product), or platform-based process (the common and sharable process for multi-types of products, such as the office's environmental performance, the employees" transport, etc.).

This process-oriented life cycle assessment contributes a holistic and creditable method to improve the global environmental performance which is required by environmental management system. The results might also support the completeness of product-oriented LCA.

Similar with product-oriented LCA, according to the standards of ISO 14040 and ISO 14044, the typical analysis process of process-oriented LCA includes also 4 steps:

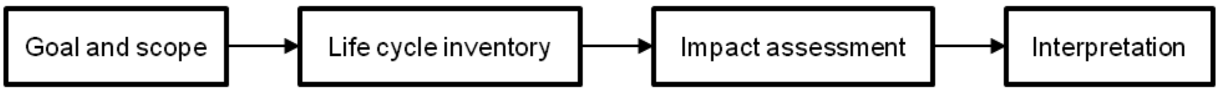


Figure 33: The process of process-oriented LCA

The details of each phase could be consulted the description in product-oriented LCA chapter.

Process-oriented streamlined Life cycle assessment

Similar with product-oriented streamlined life cycle assessment, to limit a vast data requirement to answer some specific needs for process environmental performance improvement, some streamlined life cycle assessment tools have been developed to restrict the assessment to one specific indicator. The energy consumption, the material and CO2 indexes are highlighted for this type of assessment.

The streamlined LCA is a straight and simple tool to answer some specific needs. The main weakness of this approach is the lack of an analysis and highlight system to avoid the environmental impacts transfer.

Existing tools of "process-oriented streamlined life cycle assessment"

Carbon accounting

Carbon accounting, or named as "Green House Gas accounting", "Carbon footprint", "Bilan carbone" [ADEME] refers a set of processing to "measure" amounts of CO_2 equivalents emitted by an organization. Quantifying GHG emissions will help the company to understand what the key emission sources are, how organization contributes to global emissions, and what opportunities to reduce your emissions. Finally, these assessments are to provide a factual ground for carbon-related decision-making, such as the development of a carbon reduction plan and solutions, the limit of emissions from future activities.

Several approaches have been published to guide the realization of assessment. The ISO 14064, GHG Protocol, ADEME's "Bilan carbone" and the carbon trust "PAS 2050" are some highlighted guidelines. The typical calculation process is described as follow:

1. Decide on the method to be followed	**2. Define systemic and operational boundaries**	**3. Collect the data**	**4. Apply emissions factor**	**5. Verify the results**	**6. The reduction plan (Optional)**

Note:

1. ***Decide on the method to be followed***: *Above four mentioned methods could be considered as the creditable methods to be applied.*
2. ***Define systemic and operational boundaries***: *Set clear, explicit boundaries on which parts of the organization are included in the footprint. This can be complex if there are many subsidiaries, joint ventures or leased assets. The operational boundary determines which emission sources will be quantified. It should include the full range of emissions (direct emission and indirect emission) from activities under your operational control.*
3. ***Collect data***: The accuracy of carbon accounting lies on the quality of data collected. The definition of data unit is necessary to be pre-defined and registered.
4. ***Apply emissions factors***: *The carbon accounting is measured and presented by tones of CO_2 equivalent emission. Some available factors and transformation standards could be considered.*
5. ***Verify the results***: *A technical review to ensure the creditability of evaluation results. A third party organization might be involved into this step.*
6. ***The reduction plan***: *According to the measure results, an optional action is proposed which set up a emission reduction plan to optimize the CO_2 emission.*

Figure 34: The action processing for organizational carbon accounting (Source [Carbon trust, 2012])

Actually, some Life cycle assessment software could directly support this assessment. But similar with other life cycle assessment, the primary data is preferred to measure the real situation.

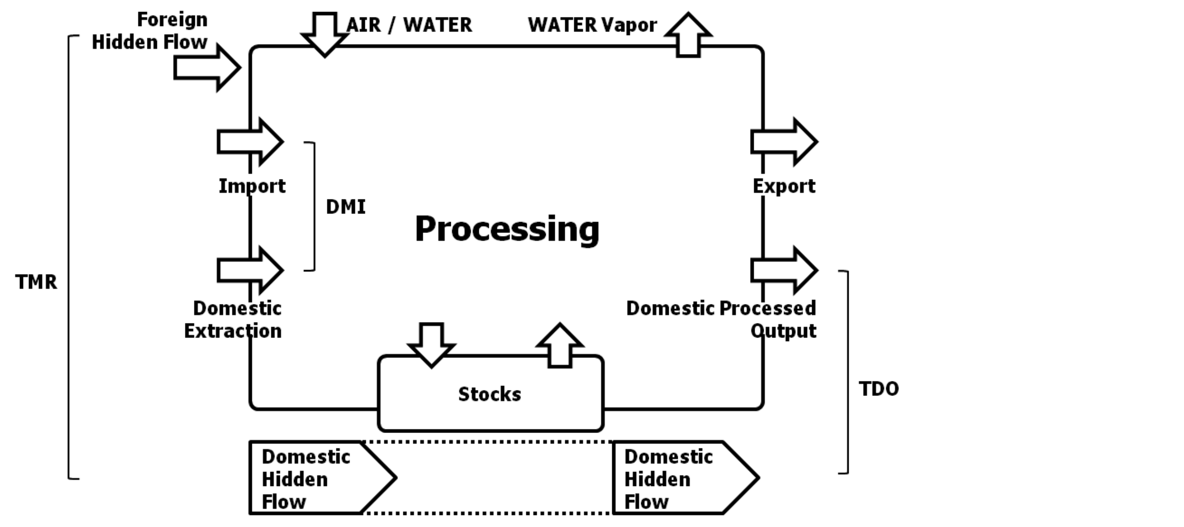
Material Flow Analysis

Material flow analysis (MFA) is a systematic assessment of the flows and stocks of materials within a system defined in space and time [Brunner P.H., 2003]. MFA is generally used for evaluating the material's consumption, balance and efficiency of a predefined organization (the firm, the industrial sectors, etc.) or geographical region. MFA might also be applied at product level or at material/substances level. This MFA could directly support the industry to [Gregory J., 2006]:

- Control the pathways of material / energy using and industrial process, assess relevant flows and stocks quantitatively, checking mass balance, sensitivities, and uncertainties
- Avoid the hazardous substance/material
- Reduce the material's outputs (dematerialization)
- Specially, control the emission, pollution and the waste of industrial process
- Optimize the industrial practices by creating a material's closing-loop process
- Monitor the process and present system results in reproducible, understandable, transparent fashion

The generic process of MFA [Cencic O. 2008]:

- Identification of the key material flow related issues.
- System analysis (selection of the relevant goods, processes, indicator substances, and system boundaries- defines start and end of flows).
- Quantification of mass flows of goods and of indicator substances.
- Identification of weak points in the system.
- Development and evaluation of scenarios by a set of indicators.
-



Inputs	DMI[3] = Domestic Extraction + Imports[2]
	TMR[4] = DMI + Domestic Hidden Flows[5] + Foreign Hidden Flows
Outputs	DPO[6] = Emissions + Waste = DMI – Net Additions to Stock – Exports
	DMO[7] = DPO + Exports
	TDO[8] = DPO + Domestic Hidden Flows
Consumption	DMC[9] = DMI -Exports
	TMC[10] = TMR – Exports – Hidden Flows from Exports
Balance	NAS[11] = DMI – DPO – Exports
	PTB[12] = Imports – exports
Efficiency	Material Productivity = Input or Output/GDP
	Resource efficiency of materials extraction = Unused[13]/used (DMI) materials

Notes:

1. *This is common impact list. According to different needs, the indicators evaluation could follow the individual definition. Ex: The definition of "efficiency" indicator – "Material productivity" have to consider*

the application perimeter. The GDP is referred to national analysis, and the turnover is for company's level. 2. *Import: The flows/fluxes across system boundaries* 3. *DMI: Direct Material Input* 4. *TMR: Total Material Requirement* 5. *Hidden flow: The material flow which doesn't import into manufacturing process* 6. *DPO: Domestic Processed Output* 7. *DMO: Direct Material Output* 8. *TDO: Total Domestic Output* 9. *DMC: Direct Materials Consumption* 10. *TMC: Total Materials Consumption* 11. *NAS: Net Additions to Stock* 12. *PTB: Physical Trade Balance* 13. *Unused: hidden or indirect material*

Tableau 80: The indicators list of MFA tools

Comparing with life cycle assessment, MFA studies might be considered as a quantitative method to prepare a material-based life cycle inventory. The "Life cycle Impact assessment" phase is a second indicator evaluation method by using the MFA results.

Similar with life cycle assessment, there are several computer based software have been developed. The "Gemis" and "STAN" are two examples. The LCA software "Umberto" also supports the MFA studies.

MFA-Gemis[1,2]
GEMIS is a free-license quantitative life-cycle/material flow analysis tool to material production and transport service, developed by Germany Öko Institut. The integrated database covers direct and indirect material flows, construction/decommissioning, energy flows (fossil, nuclear, renewable), materials (metals, minerals, food, plastics…), and transport services (person and freight), as well as recycling and waste treatment. The principal data is based on EU-27 data. Some other local versions (US, CN, IN, MX etc.) are available for some special cases. The environmental indicators are selected lies on the material flow analysis. Several specific environmental indicators, like the air emissions, greenhouse gases, liquid effluents, solid wastes, land use and resource use (primary energy and primary material demands) is able to be calculated. In addition, costs and labor impacts (direct and indirect) could be considered to complete the studies on material efficiency.
MFA-STAN[1,3]
The software STAN (short for subSTance flow ANalysis) is a freeware that supports material flow analysis (MFA) according to the Austrian standard ÖNORM S 2096 (Material flow analysis - Application in waste management) under consideration of data uncertainties. The STAN builds a graphical model product/process system by selecting the related pre-defined modules which include the components (the material flow, processes, subsystems, system boundaries and text fields), the known data of physical units (mass flows, volume flows, stocks, concentrations and transfer coefficients), different hierarchical layers (good, substances and energy) and different time periods. Some algorithms are involved to reconcile the uncertain data. And then the statistical tests are available to detect the gross errors in the given data set. The MS Excel type of interface is used to import and export the data. The final results of material/substance flow displayed as "Sankey" arrows (the width of the flow means the value). A free copy of STAN is available for downloading under www.iwa.tuwien.ac.at.
Notes: [1] *Resource of Major information comes from the European committee website – joint research center http://lca.jrc.ec.europa.eu/lcainfohub/toolList.vm* [2] *The data base is available on web-site with license free: http://www.gemis.de/*

[3] *The official presentation of software STAN*   *http://iwr.tuwien.ac.at/fileadmin/mediapool-ressourcen/Bilder/STAN/stan-info-en.pdf*

Tableau 81: Two computer based MFA software

Waste management

Waste management is a significant issue of environmental protection. A whole process of waste treatment includes the actions of collection, transport, disposal, landfill and additional issues, like monitoring and management for waste material. The final objective is generally undertaken to reduce their effect on health, the environment or aesthetics. All types of waste material, whether they are solid, liquid, gaseous or radioactive fall within the remit of waste management. As the synthesis of [Cagno E., 2005], there are three different types of waste treatment (recycling) scenarios for industrial area:

- Process recycling: The waste could be directly and immediately recycled in the manufacturing process
- On-site recycling: The waste is treated and recycled by the manufactory
- Off-site recycling: The waste will be treated or recycled by external end of life treatment center.

For each scenario, the environmental impacts of treatment process and actions should be evaluated to avoid the pollution transfer. Beside of best available technologies, the life cycle assessment approach has been consulted to calculate the streamlined end of life indicators.

WAMPS
WAMPS is an LCA based screening tool for assessing environmental and economic aspects of different waste management strategies.
WISARD
Waste Management Life Cycle Assessment software tool (WISARD) is the computer based software to support the decision maker to evaluate alternative waste management scenarios.
WRATE
WRATE (Waste and Resources Assessment Tool for the Environment) is waste management Life Cycle Assessment (LCA) software developed by the Environment Agency of England and Wales.   WRATE uses a life cycle approach to predict the environmental consequences of integrated waste management systems for municipal solid waste. It can achieve this for all life cycle stages including: home composting, waste collection, transport, transfer, pre-treatment, treatment, recovery and disposal.
Notes: [1] *Resource of Major information comes from the European committee website – joint research center*   *http://lca.jrc.ec.europa.eu/lcainfohub/toolList.vm*

Tableau 82: The waste management evaluation tools

Legislation/Regulation/Standard

Environmental law, which draws from and is influenced by principles of environmentalism, including ecology, conservation, stewardship, responsibility and sustainability, is an efficient and frequently-used tool to require the industries to protect the environment and sustainability of future human society. Since 1970s, the Europe has focused on the environmental protection. Till today, all main industrial countries have established a set of laws that cover several significant environmental impacts: the air, solid and water pollution, the conservation of resources, the biodiversity, the waste management, the energy saving, etc.

According to the implementing area, the environmental laws are divided into two major sub-areas: the laws target to the environmental impacts on final product, and the others hit the manufacturing, logistic, and end of life treatment process. According to the implementing topics, these laws might be divided into two subjects: the resource conversation and management, and the pollution control and remediation. But according to the environmental laws' contents, these laws might also be divided into three formulas: the establishment of mandatory threshold value for environmental issues (Air, water emission, recyclability rate and prohibition of hazardous substances, etc.), the suggestions and guidelines for global environmental impacts improvement and the management system to generate, organize, follow up and register the environmental related data and idea.

The environmental law provides a development tendency with a set of requirements for all related companies. It's very efficient to push the industry to upgrade the concepts and technologies and reject the backward manners.

Existing "environmental legislation, regulation and standard"

Till now, several environmental laws have been established worldwide. The next table X summarizes some examples in European area for multi-environmental impacts. And the table X shows the international legislation situation for same environmental topic (The energy efficiency).

Air quality, emissions and noise	Emissions of atmospheric pollution	Directive on emission ceilings
		Directive on concentrations of sulphur dioxide, nitrogen dioxide and nitrogen oxides, particulate matter and lead in air
	Volatile organic compounds	Directive on emissions of volatile organic compounds that result from the storage of petrol
		Directive on emissions of volatile organic compounds resulting from certain industrial activities
		Directive on emissions of volatile organic compounds due to the use of organic solvents
	Industrial plants	The Integrated Pollution, Prevention and Control (IPPC) Directive
	Noise	The EU's overall strategy on noise reduction
		EU noise legislation
		Relevant Health and safety legislation
		A full list of equipment covered by the rules and national organizations that are authorized to check compliance
		General motor vehicles
Chemical	Substance	Regulation on the Registration, Evaluation, Authorization and Restriction of Chemicals - REACH
		Restriction of Hazardous Substances Directive - RoHS
		Hazardous material prohibition law [Policy center, 1999]
Environmental management	Management	The Eco-Management and Audit Scheme
Waste	Waste management	Council Directive 99/31/EC of 26 April 1999 on the landfill of

		waste
		Directive 2008/98/EC on waste (Waste Framework Directive)
		Waste list Decision 2000/532/EC
		Directive of waste electrical and electronic equipment (WEEE)
		Environmental Protection Act 1990
		Climate Change Act 2008
		The Waste Batteries and Accumulators Regulations 2009
Climate change	Climate change	Directive 2009/31/EC of the geological storage of carbon dioxide
		Directive 2009/28/EC of the promotion of the use of energy from renewable sources
		Directive 2003/96/EC of the taxation of energy products and electricity
Information	Information	Directive 2003/4/EC of access of environmental information
Notes: *The major data is consulted by the website of European commission*		

Tableau 83: The party list of European environmental laws

	Countries																																
	Australia	Algeria	Barrain	Brazil	Canada	Chile	China	Colombia	Costarica	Ecuador	Egypt	E.U.	Ghana	Hungary	India	Indonesia	Iran	Israel	Korea	Malaysia	Mexico	New Zealand	Peru	Philippines	Russia	Saudi Arabia	Singapore	Switzerland	Taiwan	Thailand	Tunisia	U.S.A.	Venezuela
Electric/Water Chillers - Refrigo	X	X	X	O	X	X	X	X	X	X	X	X		X	X	X	X	X	X		X	X	X	X	X			X	X	X	X	X	X
Air Conditioners/ HVAC	X	X	X	X	X		X	X	X		X		X		X	X		X	X	X	X	X		X	X	X	X		X	X	X	X	X
Washing machine/dishwasher	X	X		X	X		X				X	X				X		X	X	X	X		X		X			X				X	
Printer	X						X												X						X			X	X				
Ballast	X				X		X	X	X			X						X	X	X		X		X						X		X	
Lighting	X	X		X	X	X	X	X	X				X		X	X		X	X		X	X		X	X				X	X		X	
Lighting System					X													X			X												
Television	X						X					X			X	X			X			X			X			X					
PC/Monitor	X						X												X						X			X					
Water heater	X				X		X	X	X			X				X		X			X	X			X				X			X	
Cooking appliances	X	X		X	X		X		X									X	X						X			X				X	
Heater	X																								X							X	
Boiler or hearting boiler					X							X						X	X										X			X	
Contactor							X																										
Transformer	X				X		X								X			X				X											
Motor				X	X	X	X	X	X			X			X			X	X	X	X	X		X					X	X		X	
Electric toilet																																	
Pump (Domestic)	X				X																X												
Power Suppliers	X																	X	X			X											
Battery Charge																			X														
Phone																			X														
Dehumidifier					X																								X				
Iron							X									X				X													
Standby mode	X						X					X																				X	

Tableau 84: The list of international energy consumption laws

Life Cycle Cost Analysis

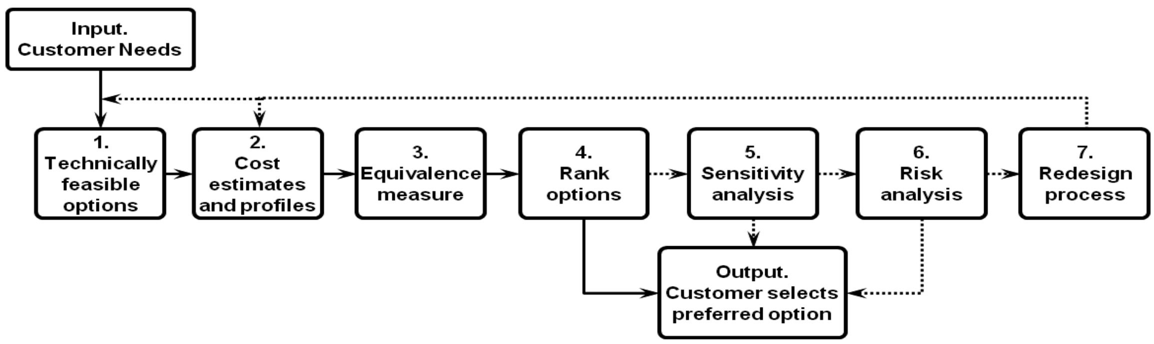
Life-cycle cost (LCC) analysis is a method for evaluating whole relevant costs over time of a project, product, or a process. The product-oriented life cycle cost comprise all costs attributable to a product from conception to those customers incur throughout the life of the product, including the costs of installation, operation, support, maintenance and disposal [Dunk A.S., 2004]. The process-oriented LCC method takes into account the first costs (or initial cost) and the "future cost". The first cost includes the capital investment cost, purchasing and installation cost (for manufacturing process); future costs, includes energy costs, operating costs, maintenance costs, capital replacement costs and any resale, salvage or disposal cost [U.S. Dept. of energy, 2005].

The implementation of life cycle cost analysis can:

- The holistic overview of cost impacts from the product's development through manufacture, distribution, customer use, disposal and potential recycling.
- Focus on post-sale factors that have become a larger percentage of life cycle costs, including warranty, cost of parts, service and maintenance, as well as being increasingly important to customers in their purchasing decisions. [Murthy D.N.P.,, 2000], [Dunk A.S., 2004]
- Support a better product's or service's price decision by a detailed entire life cycle cost analysis
- Analyze and optimize the cost planning during the whole life cycle of product/process by comparing with actual cost contribution index.
- Improve the profitability of product or organization.

[Christensen P.N., 2005] thinks that the life cycle cost analysis process is a bridge between the company and the customers. The whole life cycle cost analysis might provide the best or multi-options to customers to identify a more suitable one. With a literature, the author identifies that the life cycle cost analysis is focusing on the customer satisfaction. Several authors illustrated it more clear that this type of cost analysis is an effective interface between environmental regulation and organizational interests which significantly affect the product design, operations and maintenance decisions, recycle and reuse activities, as well as disposal methods [Zhang, H.C., 1997], [U.S. EPA, 1995].

Life cycle cost analysis is based on a deterministic "root" procedure [Christensen P.N., 2005]. This root procedure starts from customer needs and ultimately ends with the customer selecting a preferred design options. Here, the "customer" could means both the external final users of products or services and the internal decider to select the cost-saving option for product design or process management.



Notes:

1. *Cost estimates and profiles: this step is to generate the cost profiles corresponding to each feasible technical option. The cost profiles need to include the cost analysis of planning, construction, maintenance, support, use and end of life phase. [Barringer H.P., 2003] summarized also that the life cycle cost is divided into two main sub-classes: "acquisition cost" or "manufacturing cost" present the up-stream cost, and "sustaining cost" to summarize the down-stream cost. To ensure the accuracy of analysis results, a summary of activities, their occur timing and cost owners should be clearly defined. This summary need to also carefully breakdown the cost into each action – In some articles, these contents are*

identified into the predetermined bounds which support the completed definition of feasible options.

2. *Equivalence measure: the normalization or equivalence transfer is necessary to establish a comparable, creditable and common data platform which allows the further comparison and decision-making in next steps. In this phase, the "straightforward application time" is an efficient tool.*
3. *Rank options: this step requires making the life cycle cost priority of all feasible options.*
4. *Sensitivity analysis: this analysis involves the perturbation of model variables over predetermined bounds to determine the relative effect on out outcome. So this analysis need to list the subsets of model variables that significantly affects the costing results.*
5. *Risk analysis: the analysis is based on the results of sensitivity to address the details of perturbations of each technical option. The risk analysis might drive the multi-attributes: the completed decision-making data to support the selection of customers, the specification of product/option and function redesign.*
6. *Redesign process: According to the previous analysis, the redesign process is to modify, optimize the actual technical options. According to the different design dept, the results of redesign process could either modify the cost profiles (functional and partial redesign) or re-initialize the new feasible technical options.*

Figure 35: The life cycle cost analysis procedure (Source [Christensen P.N., 2005], [U.S. department of transportation, 2002], [Barringer H.P., 2003])

The life cycle cost analysis is considered as a necessary contribution to complete the product or process-oriented environmental performances. This additional analysis can ensure the "environmental efficiency" of new concept. According to above procedure, since the generation of each new environmental technical improvable option, a completed life cycle cost might be involved into the LCA procedure to evaluate the economic impacts. Finally, a completed specification, both for new product concept and for new technologies of process, could be released to involve the environmental and economic aspects into consideration.

Beside of the standard LCA, the life cycle cost analysis might also be associated with others streamlined LCA tools, such as the material flow cost accounting [Ayes D., 2010], etc.

Collaboration with recycler

In order to optimize the product's end of life performance, a specific collaboration with recycler is a business-based method. This collaboration requires the company directly contacts the recycler, shares the end of life treatment information, the professional experiences and the improvable opportunities. [Korean Electronic Association, 2008] provides a general framework (summarized in figure X) for bidirectional recycling information sharing between the manufacturer and recyclers. This sharing system can support the raising of product's recyclability by the improvement both in design phase and recycling phase.

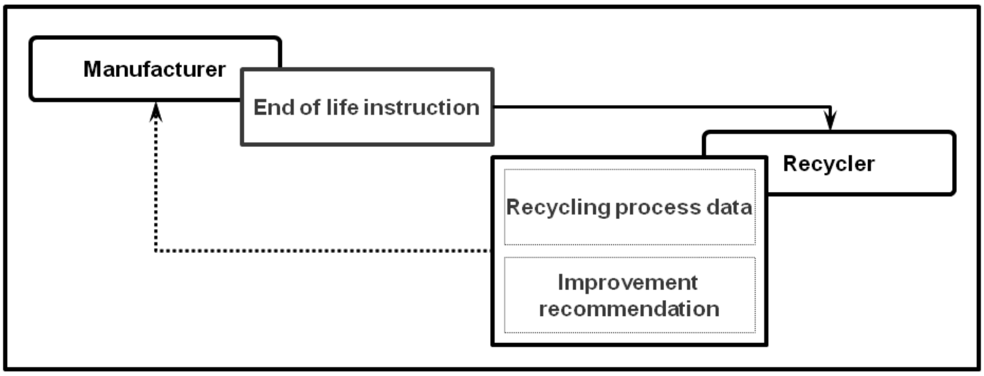


Figure 36: Framework of collaboration with recycler

In this framework, the data sharing and collaboration is ensured by diffusing the recycling-concerned documents. From manufacturer, the product provider, have to analyze and release an "End of life instruction" to provide the theoretic end of life treatment suggestion. The product provider has the detailed product's technical data which is useful to support the disassembly and other treatment process. The final objective of the end of life instruction is to avoid the "unconsciousness" during the treatment process which ensures the efficiency and the safety during the treatment process. Several scientific authors and industrial practice provide some sample to prepare this end of life instruction.

No	Topics	Description and examples
1	Product description	Identify the covered product list + product description (Weight, Volume, color and material list, etc.)
2	Law responsibility	WEEE, REACH, regulations for hazardous material, and other law related with end of life treatment Law associated with process (emission,)
3	Hazardous material list and position	JIG of EICTA, CECED and EERA list
4	Impacts and suggestion on worker's safety	Noise, temperature, electric shock or explosion etc.
5	Disassembly procedure and instruction	The steps of disassembly, including related component lists, position, dismantling methods etc.
6	Disassembly tools	Description of tools, number of tools, support machine and work lord (Timing for treatment)
7	Remanufacturing contact	The telephone number, email of remanufacturers
8	Recycling information	Identify the recyclability rate or related material mass
9	Shredding, landfill and other suggestion	

Reference:

- *WEEE directive, [Korean Electronic Association, 2008]*
- *Volvo – "Environmental declaration"*
- *HP – "Product end of life disassembly instruction"*
- *Schneider Electric - "End of life instruction"*
- *PLANAR – "Product end of life instructions"*
- *DELL – "Product end of life instruction"*

- *PALM – “Product End-of-Life Disassembly Instructions”*

Tableau 85: The contents of end of life instruction

The feedback from the recycler provides the primary data associated with the end of life treatment. At first, the recycler could map a detailed treatment process and transfer the related data to company, including the method and sequence of treatment process, the recycling rate of products, the achievability of dismantling parts and the working times required, etc. This primary information might support the company to evaluate the real performance of product’s end of life performance. According to real difficulties and performance in treatment process, secondly, the recycler might propose some improvable recommendations to designer which might drive the “design for end of life”. The recommendations could focus on the problems associated with applicability, the environmental process impacts, the safety and working environment and the low cost. Reversely, in order to raise the recyclability of product, the designer will update the requirement of new treatment methods. Finally a new contract between recycler and manufacturer could be resigned to release the collaboration.

[U.S. EPA] requires the company launching a preparatory study to evaluate and select the suitable recycler in certain geographic region, such as the local coordinator or global international partner. For different partner level, the collaboration manners and contents are different. To ensure the success of the cooperation, some support activities need to implemented, including frequent communication, the commutative training of product and treatment procedure, monitoring of cooperation, business opportunities co-analysis and the business partner channel, etc.

Reverse and closed-loop supply chain management

Does the material is recycled and how to improve the recyclability of products? One of the answers is to optimize the efficiency and the profitability of the whole turn-back system. Which components or product need to be recycled, how to organize the location of collection points, how to organize the transport between the collection points to distributors or manufacturer, and does and how to integrate the turn-back system into the normal supply chain system, in order to treat about these questions, the reverse and closed-loop supply chain management (RL and CLSCM) has been studied and proposed to focus on the organization of all operations related to the reuse, remanufacturing of materials, components and whole products. This approach contributes to organize an efficient process of planning, implementing and controlling of the recycled material and components flow which will return and might be integrated into the normal supply chain and logistic network (such as the occupancy of the storage and transportation).

Generally, the "RL and CLSCM" involves two great categories of topics: the corporate definition of EoL alternative scenarios and the management of logistic network.

The "EoL alternative scenarios definition" category needs to identify the targeted material, components or whole product will be used and recycled as a new resource. In this category, the technical review to actual product's recoverability and the financial review of profitability are necessary and two common tools need to be involved. At technical level, the pre-definition of product's EoL scenarios is a first step. As mentioned into the chapter "Design for recoverability", there are five options: direct reuse, repair, remanufacturing, recycling and disposal. The decision model to select between these options requires the consideration of various factors such as the environmental impacts, the laws, the cost and the technical treatment level, etc. [Ilgin M.A., 2010] summarized 29 tools to alternative select the scenarios. It's noted that the product design has a strong impact on the scenario definition. [Krikke H., 2003] and [Krikke H., 2004] identified the role and the impacts of the product design. Typically, the analysis and the improvement of the product's modularity, reparability, recyclability and the related removable and re-assemble structure are prioritized. By summarizing each product's recoverability analysis, a technical review at corporate level is necessary to prepare a set of candidates of target products. [Veerakamolmal, P., 1999] and [Pochampally, K.K., 2009] proposed the model and cost benefit functions to guide the selection the best product for reprocessing from this set of candidates.

Secondly, in order to organize the logistic network, some topics are important to be considered:

Network design

In face to the multi-objectives recovering material, components and whole products, a logistic network design is necessary to ensure the efficiency of collection, stocking and the transportation. [Ilgin M.A., 2010] classified the network design model into two sub-categories, the deterministic model considers only the organization of the reverse flow network and the stochastic model involves also the high-degree of uncertainty associated with quality and quantity of returns. In this phase, the traditional supply chain theories and related factors are used. The operational cost, delivery timing and the delay management are focused on, and related issues, such as the number and the location of the collective points, distributor and refurbishing center, the planning and the scenarios of the transportation and the necessary stock of collected product's are analyzed and optimized.

Product acquisition management

Highly uncertain nature of quantity, quality and timing of returns requires an effective policies and management system for the acquisition of used products [Ilgin M.A., 2010]. The uncontrolled products' acquisition leads to a high degree risk of customer's un-satisfaction and low quality level. The product acquisition system could be divided as two types: the self-waste stream acquisition system and the market-drive acquisition system for no-original defined resources. For each type of sub-system, the product acquisition management set up the multiple levels controlling process (strict criteria, the technical validation, the credit of input's quality, the cash pay for high quality, etc.) which make the interface between the RL network design, production planning and controlling activities [Guide V.D.R., 2001].

Selection and evaluation of suppliers

Due to the differences between the reverse and forward flows in terms of the cost and complexity, the RL operations might be outsourced by third party logistics providers or directly by the end of life treatment center [Efendigil T., 2008], [Meade L., 2002]. In order to make the decision of the third party provider's selection, the multi-criteria methodology is necessary which analyze the compliance of technical quality and the operational financial performances. It's noticed that these evaluations might be integrated into the traditional supplier evaluation process and make highlight to product designer.

Marketing related issues

This analysis is to consider the pricing of manufactured and remanufactured products, competition in remanufacturing and selection of an optimal return corporate policy. Commonly, the multiple quality levels definition, instead of the single quality level of same product is prioritized. In other hand, this analysis considers also the treatment for unsold products. The remanufacturing and the reverse design provide an additional opportunity to deeply reduce the product's cost [Mitra S., 2007].

Performance measurement

In order to initialize the RL network and ensure the continuously improvement, the holistic performance measure system is necessary to be established. The operational impacts (including the traditional factors of supply chain) and environmental impacts (ISO 14000, LCA, etc.) are investigated. Finally, this global performance measurement could be also divided to address a single product's performances which contribute an overview of life cycle analysis.

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